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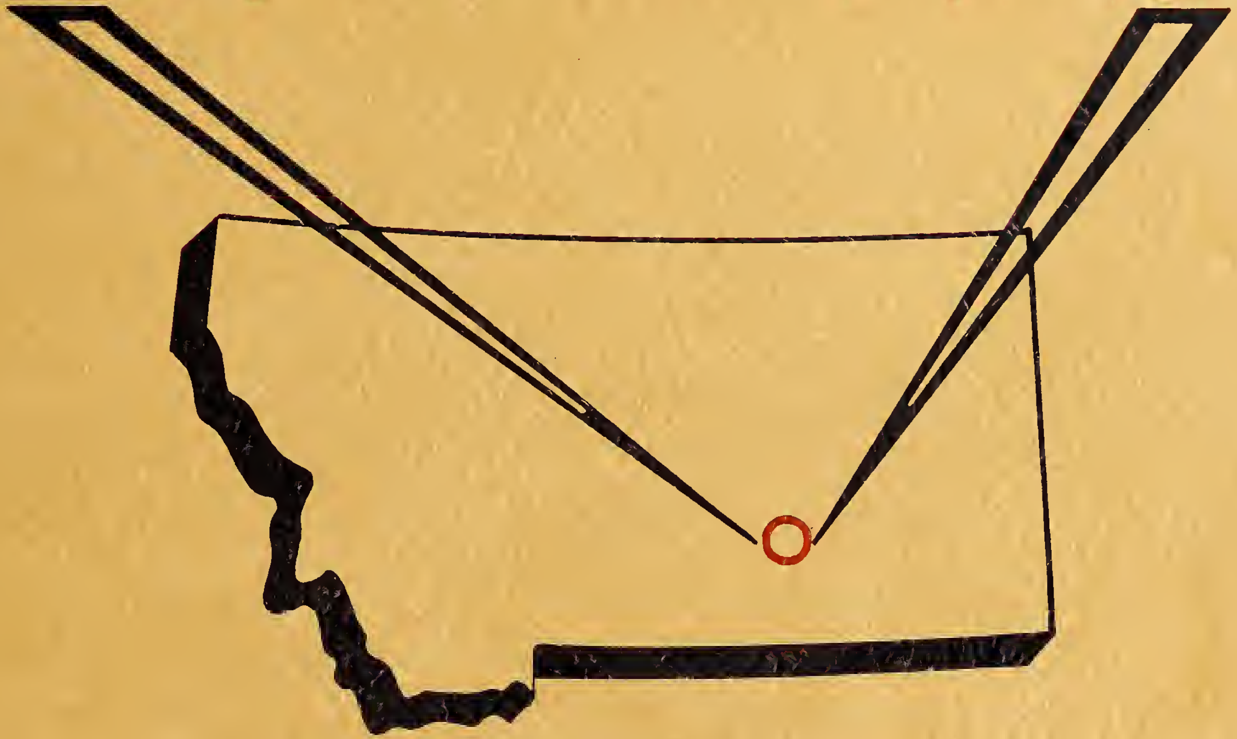
A REPORT ON LOCATION AND DESIGN

POMPEYS PILLAR TO CUSTER



INTERSTATE ROUTE 94

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A REPORT ON
LOCATION AND DESIGN

POMPEYS PILLAR TO CUSTER
INTERSTATE ROUTE 94

JUNE, 1966

PREPARED FOR
MONTANA HIGHWAY COMMISSION

PREPARED BY
MORRISON-MAIERLE, INC.
CONSULTING ENGINEERS
BILLINGS-HELENA, MONTANA

MORRISON-MAIERLE, INC.
CONSULTING ENGINEERS
1127 ALDERSON AVENUE
P. O. BOX 20257
BILLINGS, MONTANA 59102

STREETS
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HELENA OFFICE
910 HELENA AVENUE
HELENA, MONTANA

TELEPHONE 252-4707

July 22, 1966

Highway Commission
State of Montana
Helena, Montana

Gentlemen:

We are pleased to submit this preliminary engineering report and the location design and estimated cost of the proposed Interstate Highway Route 94 from the vicinity of the Town of Pompeys Pillar to the vicinity of the Town of Custer. This report conforms to the Agreement with the Montana State Highway Commission dated December 8, 1965.

The report presents proposals for alignment, grades, rest area location, and local access facilities for the most satisfactory alternates of all the many route possibilities considered. It contains our recommendation of the best of the alternates proposed herein for this section of Interstate Highway No. 94. This engineering recommendation was made after careful and thorough consideration of all the alternates considered through analysis of costs, the effect on the agricultural economy of the area traversed, and service to the highway user.

All studies and analysis were on the basis of approved Interstate design standards for the type of terrain, traffic volume, and other factors involved. Economy of construction, minimizing to the extent practical the impact on the economy of this irrigated section of the Yellowstone Valley, economy to the highway user, and safety were the prime considerations. The scenic value of the highway was considered to the point possible within the limitations set by satisfying the prime considerations.

We sincerely appreciate the opportunity to perform this important study. We gratefully acknowledge the splendid cooperation and the valuable assistance of staff engineers and officials of the Montana State Highway Department, the Bureau of Public Roads, and the members of the Highway Commission.

Respectfully submitted,

MORRISON-MAIERLE, INC.

J. A. Maierle
J. A. Maierle, President

JAM/jf

ORDER OF CONTENTS - POMPEYS PILLAR TO CUSTER - I-94 STUDY

AREA MAP OF SOUTHEASTERN MONTANA Facing Page 1

INTRODUCTION Page 1

LOCATION PLAN - Figures 1 to 4 Inclusive Following Page 5

REPORT SUMMARY AND RECOMMENDATIONS Page 6

PLATE I, Cost Summary of Alternate Alignments Following Page 10

GEOLOGY Page 11

GEOLOGY EXHIBIT, Figures 5 to 8 Inclusive Following Page 21

HYDRAULICS AND DRAINAGE Page 24

DESIGN STANDARDS AND CRITERIA Page 27

TYPICAL ROADWAY SECTION, Figure 9 Following Page 31

GEOMETRICS AND LOCATION Page 32

PLATE 2 - Geometric Summary Facing Page 33

RIGHT-OF-WAY AND LOCAL ACCESS Page 57

PLATE 3 - Comparison of Severance Damages to Local Access Costs Following Page 63

MAJOR UNDERPASSES AND DRAINAGE STRUCTURES Page 64

TYPE I UNDERPASS STRUCTURE DETAILS - Figure 10
Following Page 66
TYPE II UNDERPASS STRUCTURE DETAILS - Figure 11

MISCELLANEOUS CONSIDERATIONS Page 67

- Utilities
- Rest Area
- Division Into Construction Contract Possibilities

ECONOMIC ANALYSIS Page 74

PLATE 4, Construction Cost Comparison of Alternates Studied Following Page 80

PLATE 5, Annual Cost Summary Following Page 80

LEGEND FOR PLAN-PROFILE SHEETS, Figure 12
HILL ALTERNATE PLAN-PROFILE SHEETS, Figures 13 through 44
VALLEY ALTERNATE PLAN-PROFILE SHEETS, Figures 45 through 76
MILL CREEK CONNECTION PLAN-PROFILE SHEETS, Figures 77 through 80
THURMOND COULEE CONNECTION PLAN-PROFILE SHEETS, Figures 81 through 84
SAND CREEK CONNECTION PLAN-PROFILE SHEETS, Figures 85 through 89

PLATES AND ILLUSTRATIONS

AREA MAP OF SOUTHEASTERN MONTANA

LOCATION PLAN OF ALTERNATES STUDIED- FIGURES 1 to 4 Inclusive

COST SUMMARY OF ALTERNATE ALIGNMENTS - PLATE I

GEOLOGY EXHIBIT - FIGURES 5 to 8 Inclusive

TYPICAL ROADWAY SECTION - FIGURE 9

GEOMETRIC SUMMARY - PLATE 2

COMPARISON OF SEVERANCE DAMAGES TO LOCAL ACCESS COSTS - PLATE 3

UNDERPASS STRUCTURE DETAILS - TYPE I - FIGURE 10

UNDERPASS STRUCTURE DETAILS - TYPE II - FIGURE 11

GENERAL GEOLOGIC PROFILE - CUSTER TO POMPEYS PILLAR

TYPICAL SECTION - HELL CREEK FORMATION

CONSTRUCTION COST COMPARISON OF ALTERNATES STUDIED - PLATE 4

ANNUAL COST SUMMARY - PLATE 5

LEGEND FOR PLAN-PROFILE SHEETS - FIGURE 12

HILL ALTERNATE PLAN-PROFILE SHEETS - FIGURES 13 to 44 Inclusive

VALLEY ALTERNATE PLAN-PROFILE SHEETS - FIGURES 45 to 76 Inclusive

MILL CREEK CONNECTION PLAN-PROFILE SHEETS - FIGURES 77 to 80 Inclusive

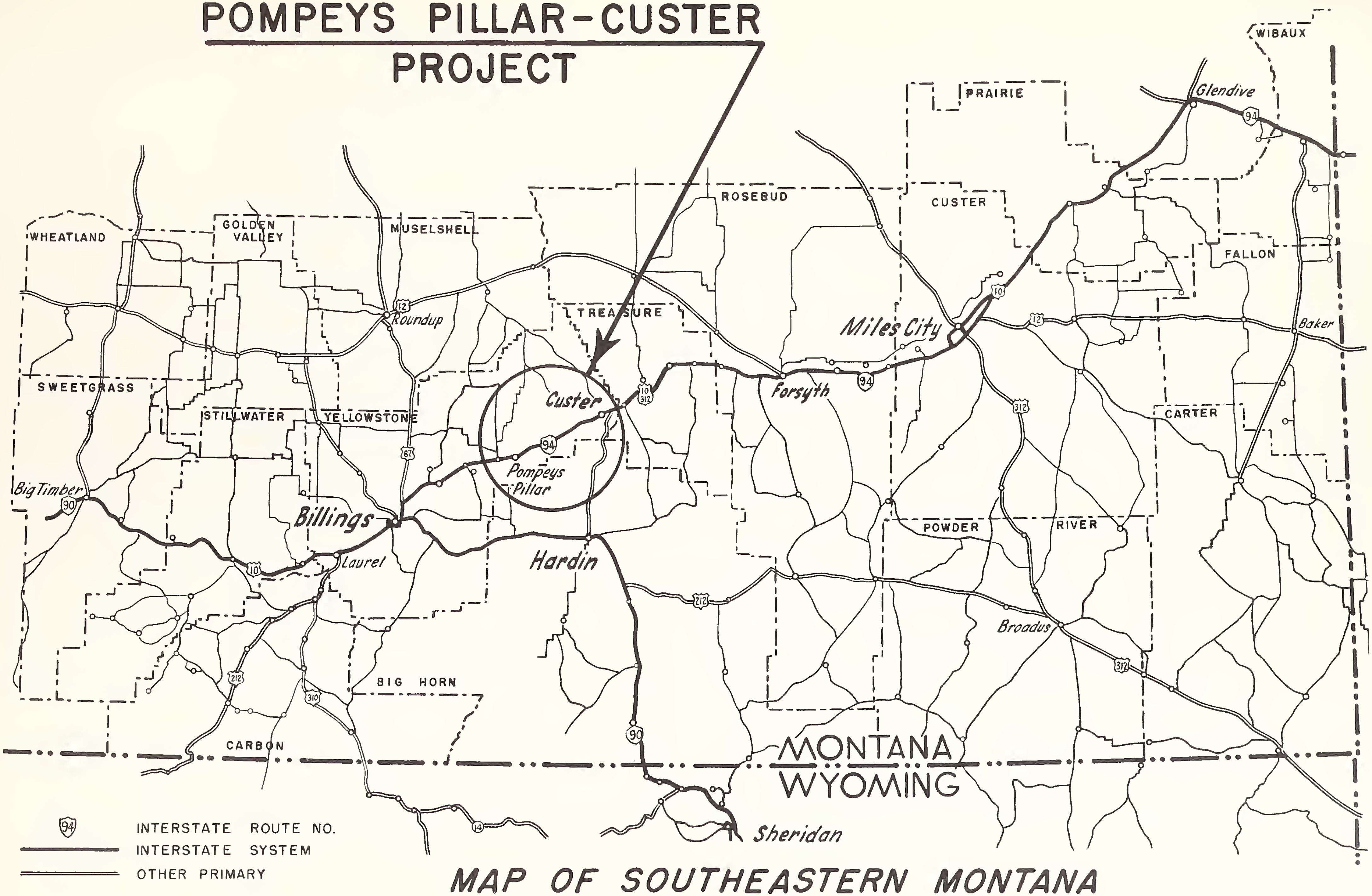
THURMOND COULEE CONNECTION PLAN-PROFILE SHEETS - FIGURES 81 to 84 Inclusive

SAND CREEK CONNECTION PLAN-PROFILE SHEETS - FIGURES 85 to 89 Inclusive

ABREVIATIONS USED IN THIS REPORT

M.S.H.C	Montana State Highway Commission
B.P.R.	U.S. Bureau of Public Roads, Department of Commerce
A.A.S.H.O.	American Association of State Highway Officials
P.T.W.	Present Traveled Way (U.S. Highway No.10)
A.D.T.	Average Daily Traffic
D.H.V.	Design Hourly Volume
M.P.H.	Miles Per Hour
c.f.s.	Cubic Feet Per Second
f.p.s	Feet Per Second
V.P.H	Vehicles Per Hour

POMPEYS PILLAR-CUSTER PROJECT



MAP OF SOUTHEASTERN MONTANA

INTRODUCTION

The authorization for this study and report covering a section of Interstate Route 94 is an agreement dated December 8, 1965 between the State of Montana, acting through its Highway Commission, and Morrison-Maierle, Inc., Consulting Engineers.

As shown on the map of Southeastern Montana, at left, Interstate Route 94 enters Eastern Montana in Wibaux County east of Glendive and from Glendive follows the Yellowstone River to a point of junction with Interstate Route 90 near Billings. This study involves a twenty-one odd mile section of I-94 beginning approximately one mile west of the Town of Pompeys Pillar and ending approximately one and one half miles westerly from the Town of Custer. These study termini have been modified from the limits spelled out in the Engineering Agreement while this study has been in progress. By an exchange of letters between the Montana State Highway Commission and Consultant dated January 31, 1966 and February 4, 1966 the easterly terminus of this location study was moved easterly one mile from the east line of Section 9, T 4 N, R 33 E to the easterly line of Section 10, T 4 N, R 33 E, the easterly terminus described above. Alternate alignments, as presented herein, extend easterly beyond the said east line of Section 10 only as is required to fully tie the Hill Route into afore mentioned I-94 alignment by Others. The point of tangency of the circular curve on the end of the Hill Route is a common point with this study's Valley Route and I-94 alignment by Others extending easterly from this study area. When the Pompeys Pillar interchange was approved by Bureau of Public Roads at a location adjacent to the grade separation where the PTW crosses the Northern Pacific Railway, approximately two miles west of the Town of Pompeys Pillar, the westerly study limit for the purposes of this report was moved easterly approximately one mile to the vicinity of the midsection line of Section 22, T 3N, R 30 E. This is the west end of study as described above and Station 0 plus 00 for the purposes of this study. The designation on the section of I-94 studied herein is I 94-1 (9) 25 Pompeys Pillar - Custer.

The information presented herein is the result of extensive engineering study by the Consultant of all route possibilities which seem practical and costwise feasible within the corridor established for this study and furnished by Montana State Highway Commission to Morrison-Maierle, Inc. under cover letter dated February 8, 1966. The forty one odd miles of alternate routing presented herein represents the results of a process of elimination based on a thorough cost study of many other alternates which were thus eliminated from final consideration and presentation in this report.

This study has been based on mapping and pictorial data prepared and assembled by Montana State Highway Commission for this type of reconnaissance study. The Consultant has made numerous field inspections of the terrain involved in order to get the proper interpretation and make the best use of this mapping and pictorial data. Thus study includes narrative, pictorial and tabular information on the following:

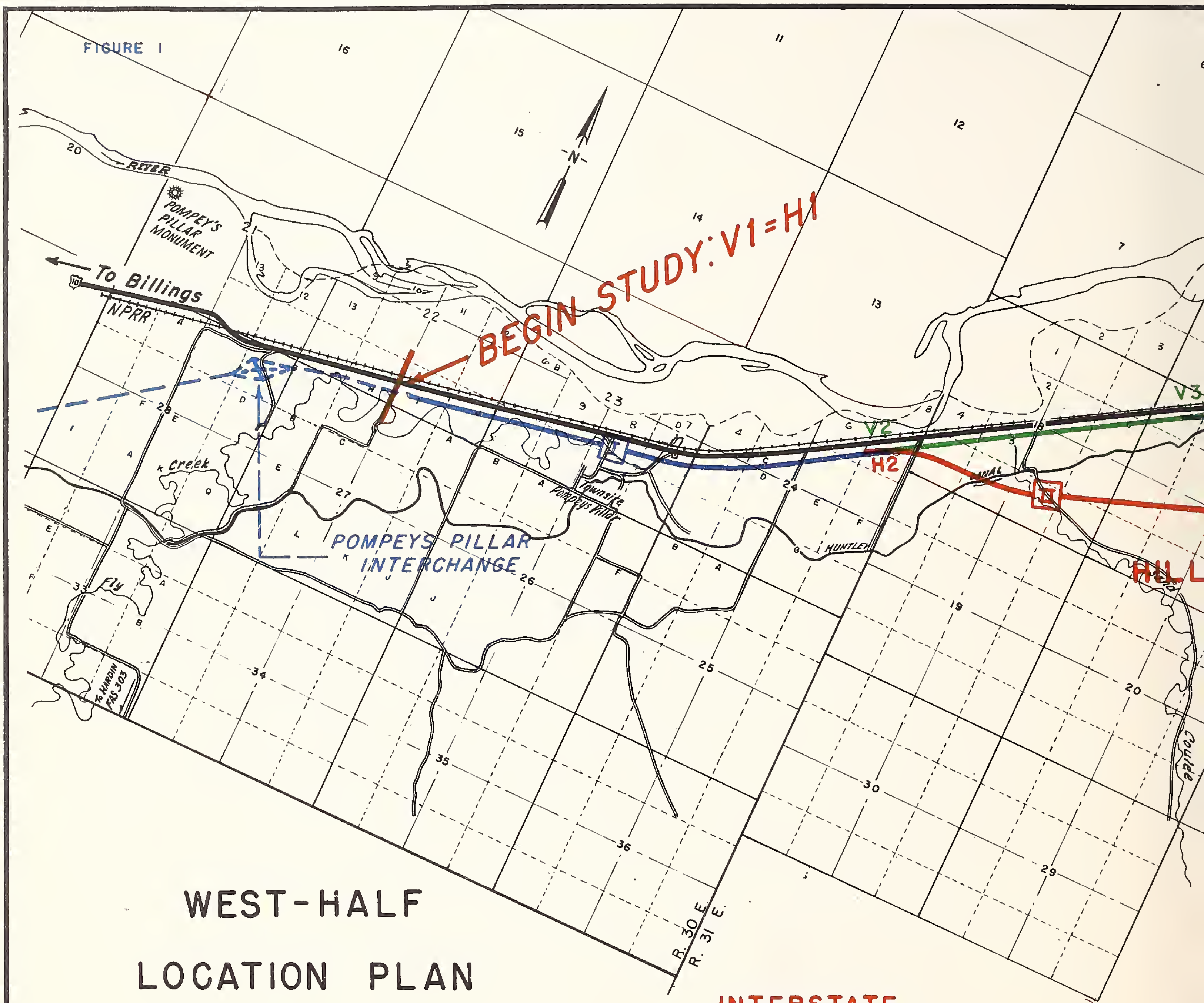
Report Summary and Engineer's Recommendation on Routing
Geology
Hydraulics and Drainage
Design Standards and Criteria
Geometrics and Location
Right-of-way and Related Items
Major Underpass and Drainage Structures
Miscellaneous Considerations Relative to Utilities, Access to Highway Maintenance Facilities and Interstate Rest Area Considerations
Economic Analysis Including All Initial Costs, Road User Costs, Maintenance Costs and Total Annual Costs.

The maps entitled "Location Plan of Alternates Studied", Figures 1 through 4 which immediately follow this Introduction, serve as a key plan to show the alternate alignments for I-94 which were selected for study in final detail and to be presented fully in this report. Shown on these maps are the relationship of these route alternates to each other and to certain physical features having an importance relative to the findings of this study; the present alignment of U.S. Highway No. 10, hereinafter referred to as the P.T.W., the Yellowstone River, local roads and major drainage courses crossed by these Interstate alignment alternates, and the Huntley and Waco-Custer Irrigation Canals which separate irrigated Yellowstone River Valley land from the dry crop and grazing land lying southerly of these canals.

For identification purposes the juction points of these various I-94 alternates have been identified by a letter-number combination; "V" for Valley and "H" for Hill with number suffixes increasing numerically from west to east. Thus, on the westerly portion of this studied area, three alternates are presented; a complete Valley Route following the P.T.W. to V4, a route following the P.T.W. to V2 = H2 and thence into the mouth of Sand Coulee to gain a hill or non-irrigated land alignment easterly of this point to V4 = H4, and finally a route following the PTW to V3 and thence via the Mill Creek Connection onto the Hill alignment easterly to V4 = H4. The confining width of the official corridor precluded other than a common line for all alternates studied from the beginning of the study area easterly to a point on the easterly limits of the Town of Pompeys Pillar. An economic study of construction and right-of-way costs of other than a PTW paralleling route precluded other than a common line for all alternates easterly from the Town of Pompeys Pillar as far as V2 = H2. At V1 = H1, the westerly terminous of this study, the first tangent on this study alignment is a projection of I-94 alignment, I 94-1(2) 6, Ballantine-Pompeys Pillar, which has been approved by the Montana State Highway Commission and Bureau of Public Roads.

Easterly of V4 = H4, preliminary cost evaluation of several alternates narrowed the choice for final study to the common route shown for all alternates from V4 = H4 through the recommended Interstate Rest Area location to V5 = H5. Easterly from this junction point four alternate routes are shown and studied in full. These are the Hill Route via H6 and H7 to the easterly end of the study area at H8 = V8, a route which would avoid all irrigated land easterly of H5. A second alternate in the easterly portion of the study area is the Valley Route which would follow the PTW to within approximately one mile of the easterly end of study at V8 before heading out of the irrigated valley and into the hills. A third easterly portion alternate is shown as following the P.T.W. to V6 and thence, via the Thurmond Coulee Connection to H6 and the Hill alignment through H7 to H8. Finally, a fourth easterly portion alternate routing is shown as following the P.T.W. through V6 to V7 and thence into the hills, via the Sand Creek Connection, to H7 and the Hill Route to H8. At V8 = H8 all studied alternates join I-94 routing, now approved by Montana State Highway Commission and Bureau of Public Roads, which extends easterly to the Town of Custer and thence easterly approximately 3.4 miles to a junction with I-94 previously constructed and now in use. Thus, for the entire study, combinations of the three westerly portion alternates and four easterly portion alternate can be made for twelve alternate possibilities from which to select this study's recommended I-94 routing. Under "Report Summary and Recommendations" which immediately follows the adjoining Location Plan maps the basic findings of this study are discussed and the Engineer's recommendation of I-94 routing are set forth, complete with reasons and cost data to support the recommendation made.

FIGURE I



WEST-HALF

LOCATION PLAN
OF
ALTERNATES STUDIED
INTERSTATE 94
POMPEYS PILLAR TO CUSTER

-LEGEND-

EXISTING

U. S. HIGHWAY 10

LOCAL ROAD

N.P. RAILROAD

STREAMS

IRRIGATION CANALS

TRAILS

INTERSTATE THIS STUDY

HILL ALTERNATE

VALLEY ALTERNATE

CONNECTIONS AND COMMON ALIGNMENT (Hill & Valley)

JUNCTION DESIGNATION V1 H1

MAJOR VEHICULAR UNDERPASS Type I or II

BY OTHERS

FIGURE 2

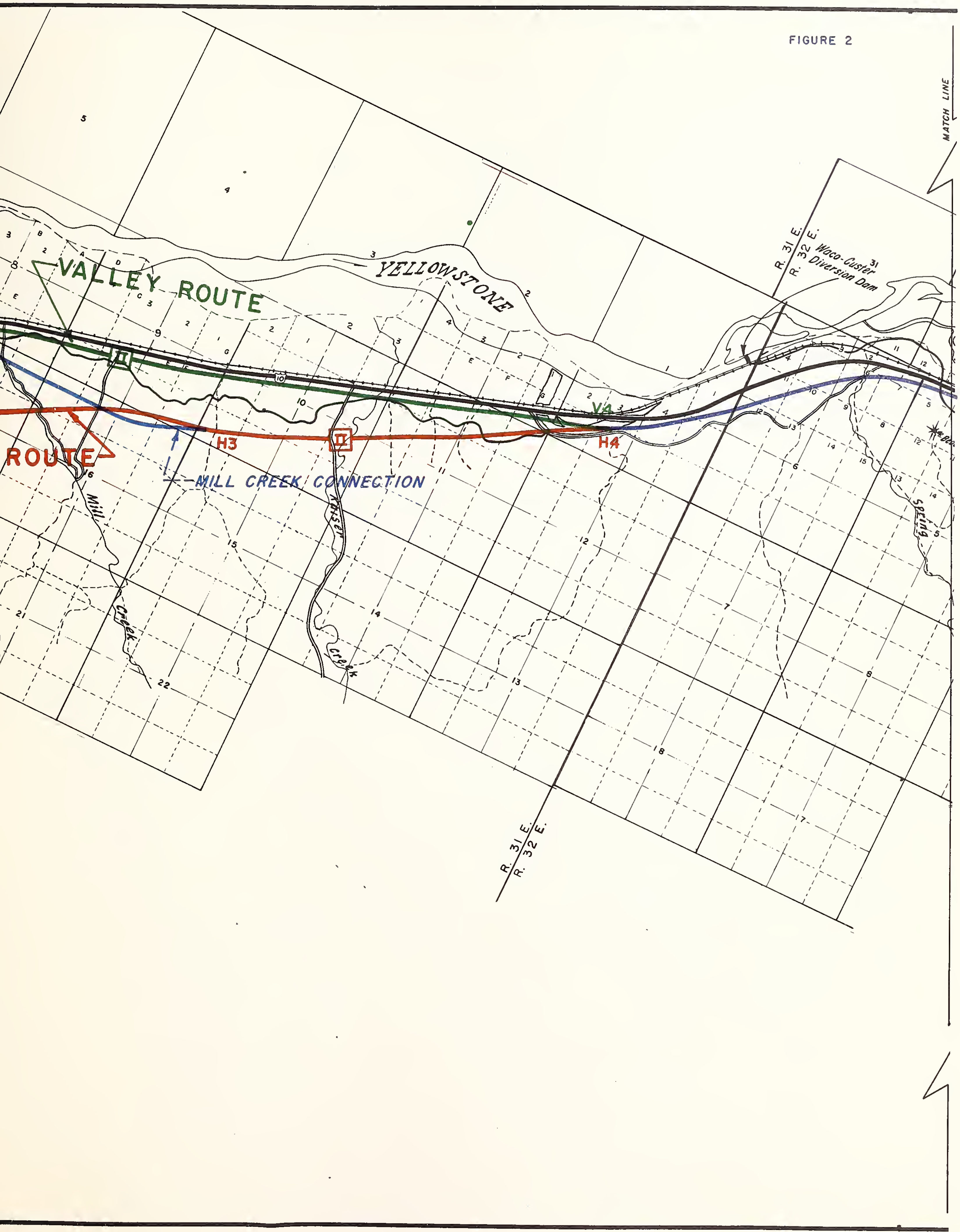

VALLEY ROUTE
ROUTE
YELLOWSTONE
MILL CREEK CONNECTION
H3
H4
V4
10
Mill
Creek
Creek
Spring
Waco-Custer Diversion Dam
R. 31 E.
R. 32 E.
R. 31 E.
R. 32 E.
MATCH LINE

FIGURE 3

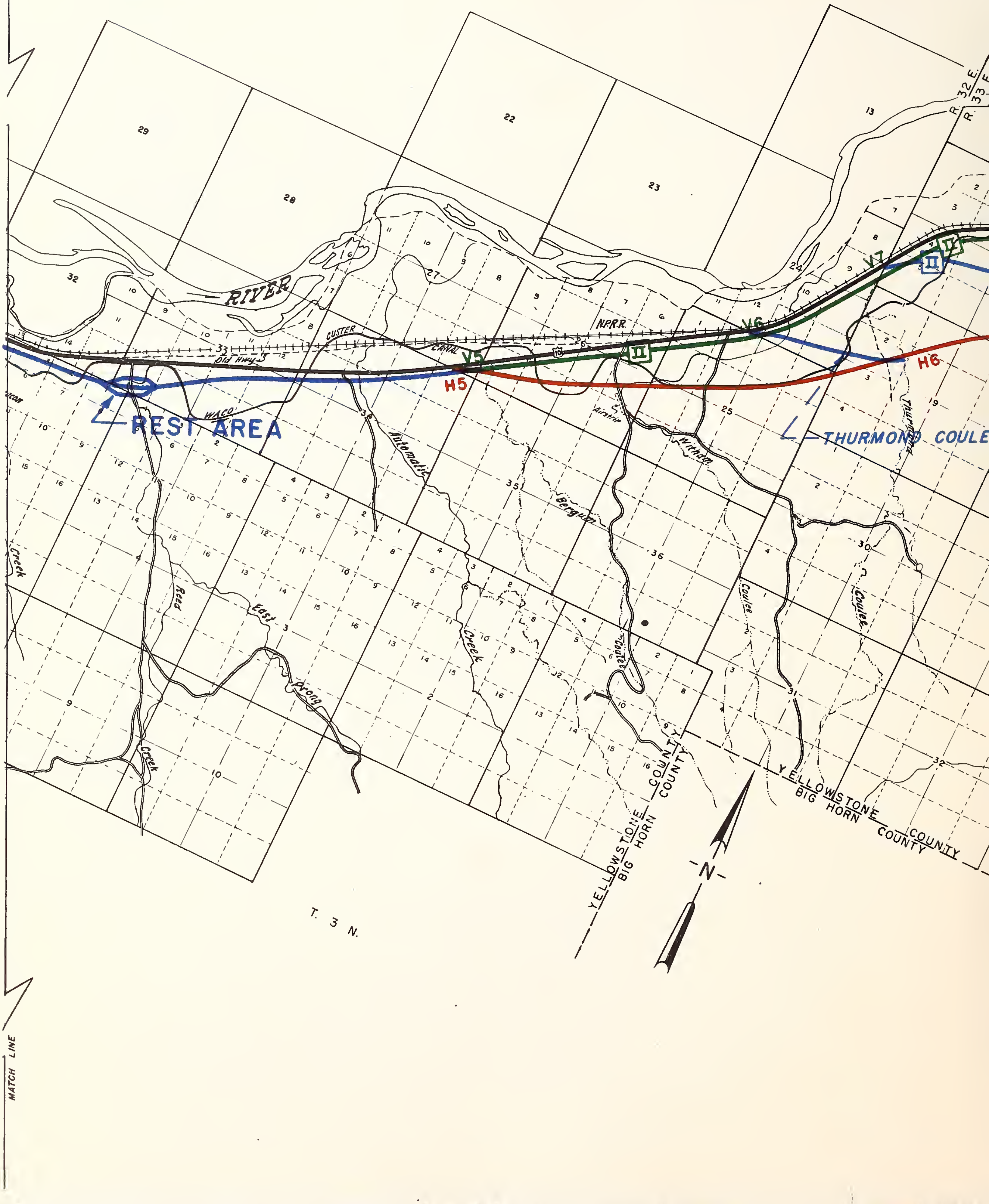
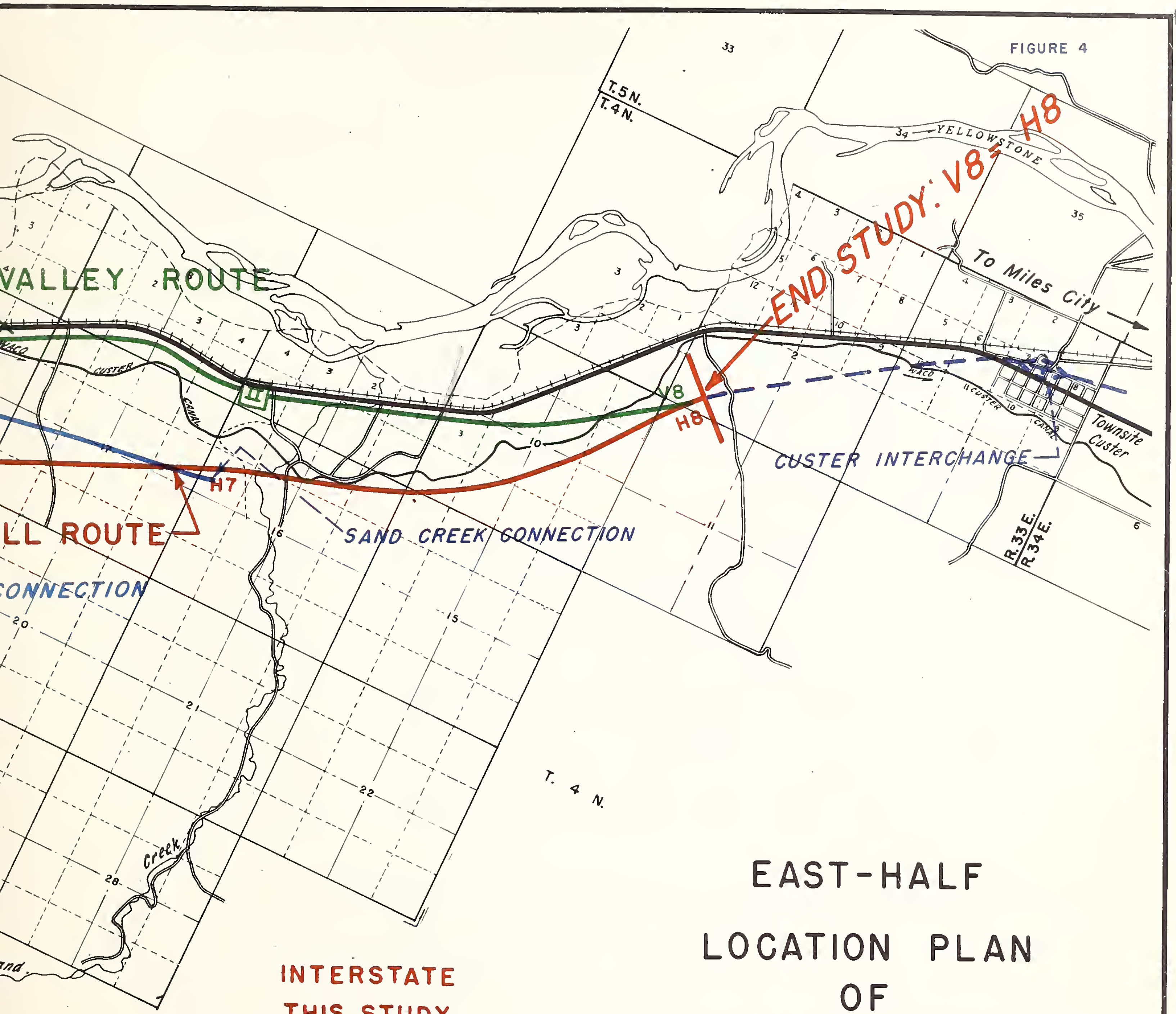

RIVER
N.P.R.R.
CUSTER CANAL
Old Hwy. 10
10
WACO
REST AREA
THURMOND COULEE
V5
V6
V7
H5
H6
II
Airstrip
Automatic
Bergum
Witham
Coulee
Creek
Reed
East Prong
Creek
Thurmond
YELLOWSTONE COUNTY
BIG HORN COUNTY
R. 32 E.
R. 33 E.
T. 3 N.
N
MATCH LINE

FIGURE 4



EAST-HALF

LOCATION PLAN OF ALTERNATES STUDIED INTERSTATE 94 POMPEYS PILLAR TO CUSTER

-LEGEND-

INTERSTATE THIS STUDY

HILL ALTERNATE	━━
VALLEY ALTERNATE	━━
CONNECTIONS AND COMMON ALIGNMENT (Hill & Valley)	━━
JUNCTION DESIGNATION	V1 H1
MAJOR VEHICULAR UNDERPASS Type I or II	─[I]─
BY OTHERS	─ ─ ─

EXISTING

U.S. HIGHWAY 10	━(10)━
LOCAL ROAD	═══
N.P. RAILROAD	┼┼┼┼┼┼┼┼┼
STREAMS	───
IRRIGATION CANALS	━━
TRAILS	- - -

REPORT SUMMARY AND RECOMMENDATIONS

The section of Interstate Highway No. 94 covered by this study and report cannot be justified for more than two lanes under current U.S. Bureau of Public Roads policy. It is proposed herein that the two lanes constructed initially be for west bound traffic of a future four lane facility. It is proposed that right-of-way be acquired initially for four lanes. For the purposes of this preliminary study, to make all alternates truly comparable, 70 M.P.H. design has been maintained throughout to provide 2300 feet of passing sight distance on all horizontal and vertical curves. On final design, when the alignment to be constructed has been selected, some modification of this strict interpretation of two lane 70 M.P.H. design criteria may be warranted in the matter of maximum grades and lengths of vertical curves, keeping in mind that a proper balance must be obtained on safety, cost of construction and the scenic quality of the highway. No interchanges were found to be economically justified within this study area.

For local traffic it is proposed that present U.S. Highway No. 10 be kept intact as a continuous north frontage with access to the Interstate at the interchanges, outside this study area, about two miles west of the Town of Pompeys Pillar and in the Town of Custer. One Interstate Rest Area is proposed for construction in this study area. It is proposed that drainage under the Interstate and frontage roads will be via structural plate culverts in lieu of bridges except for Fly Creek near the Town of Pompeys Pillar where an Interstate and county road bridge are proposed. Access to maintain this section of I-94 will be via the two interchanges described above and thus no maintanance facilities are proposed within this study area

As discussed in the previous section entitled "Introduction" and as shown on "Location Plan of Alternate Studied," Figures 1 to 4 inclusive which immediately precede this section, three alternate routes were selected for final study and presentation in this report for the westerly portion of the study area and four alternate routes were likewise selected for the easterly portion of this study. These seven east and west route alternates can be combined into twelve overall alignment combinations, hereinafter referred to as "alternate alignments." These alternate alignments are summarized, as to their initial and annual costs, on Plate I, "Cost Summary of Alternate Alignments," facing page 10.

A study of these comparative cost figures indicates that both initial and annual cost figures are so closely grouped for all alignments that this type of cost data cannot be used to conclusively arrive at the alternate to be recommended. Alignment alternates CE, AE, CD and AD have been deemed most worthy of final consideration for the recommended alignment because they are the alignments having the lowest annual cost and are within 2% of being as low in initial costs as any of the studied alignments Since the initial and annual cost picture presents such a tightly grouped list of alternates, factors other than this cost data must be considered to arrive at the recommended alignment.

Consider first the very important factor of the relationship of these alternates to the agricultural economy and pattern of land use in the part of the Yellowstone River Valley traversed by this section of Interstate Highway No.94. An all Valley Alignment (alternate designation CG) would require 92 4% of it's right-of-way area in irrigated land having a value of approximately $350 per acre as compared to an all Hill Alignment (alternate designation AD) which would only traverse irrigated land for 12.3% of its right-of-way area. These irrigated land percentages of total land required for right-of-way have been determined for the Hill and Valley alternates with line common to both alternates from V1 = H1 to V2 = H2 and V4 = H4 to V5 = H5 being excluded from the computation. This common line involves 23% irrigated land area. The requirement for irrigated land right-of-way in the Hill Alignment and on alignment common to all aternates cannot be avoided or minimized for reasons spelled out in subsequent sections of this report

The three Valley to Hill Connections offer a compromise on alignment in irrigated land between the Valley and Hill extremes. While the initial and annual costs reflect the actual cost of this irrigated land they do not measure the impact on the agricultural economy of this study area, if as in the case of the Waco-Custer Irrigation District, approximately 10% of the land in this irrigation district is lost forever. This loss could seriously effect the sugar beet economy of this portion of the Valley.

Any Interstate Highway with its controlled access features causes severance damages where it is necessary to cut through parcels of property. Severance damages in the case of an all Valley Alignment would be especially severe in this study area where 25 tracts of predominately irrigated land would be cut in two. On the other hand an all Hill Alignment would sever 24 tracts of which 18 are predominately dry crop and grazing land. All alignments studied have been provided with local access features such as frontage roads and underpasses to mitigate severance damages as much as is economically feasible but there is no practical way to measure the economic loss to an irrigated land farmer by the out-of-direction travel which would be necessary if an all Valley Alignment were selected for this section of I-94. The out-of-direction travel for local traffic with an all Hill Alignment would be much less severe especially considering the pattern of land use and the lesser number of tracts severed and the way in which they are severed.

A comparison of such geometric factors as grades, horizontal curves and vertical curves for all alignments does not reveal any significant advantage for any alignment from the standpoint of highway capacity or road user costs. Although the Hill alignment incorporates the highest safey standards possible for passing provisions for a two-lane highway, it does have more crest vertical curves and therefore is more undesirable from the vehicle drivers viewpoint. This inherent geometric feature of rolling profile alignment is less important for a four lane facility where passing manuevers can be performed without concern for oncoming traffic.

On the basis of the major considerations discussed above the recommended alignment for this section of I-94 is the Hill Alignment throughout the entire length of this study. This alignment, designated AD on Plate 1, is shown on "Location Plan of Alternates Studied," Figures 1-4 as a combination of red (for Hill Alignment) and blue (for alignment common to all alternates). This alignment via H1 = V1, H2 = V2, H3, H4 = V4, H5 = V5, H6, H7 to end of study at H8 = V8 is also shown in detail on Plan-Profile sheets, Figures 13 through 44 bound at the back of this report. The initial estimated cost of this alignment as listed on Plate 1 is $6,157,900 which makes it approximately 1.9% higher than the lowest initial cost of all studied alternates. Likewise its annual cost of $4,223,400 is about 0.2% higher than the lowest annual cost of all alignments.

These modest additional costs over the lower cost alternates are judged to be justified on the basis of the major factors discussed above and in recognition of such less significant factors weighing in favor of the Hill Alignment as ease of acquiring right-of-way, safety, proximity to sources of aggregate and the disruptive influence of future four lane Interstate construction on the agricultural economy of this valley. In acquiring right-of-way for this project it should be recognized that a substantial difference of opinion would be probable for the twenty five irrigated farm units severed by the Valley Alternate as to the value of land and severance damages resulting from Interstate construction. Condemnation action would very likely be required which could result in delays on acquiring right-of-way and higher cost than those estimated herein. Because of its more remote location relative to school bus routes, mail routes and other local traffic conditions, the Hill Alternate should provide a safer alignment. The access control fence is not likely to fully prevent youngsters from crossing the Interstate Highway on the Valley alignment if it is more convenient to them. Since sources of aggregate and borrow material will likely come from the hills, future Interstate construction for addition to four lanes will be more economical and less disruptive to the agricultural economy of the valley for the Hill Alternate as compared to other studied alternates.

The Hill Alignment as defined and discussed herein, complete with its local access features, is hereby recommended for Interstate Highway No. 94 in this study area. Early consideration of the contents of this report and deliberations relative to selecting of an approved route for this project is hereby respectfully requested. By so doing it is hoped that it will be possible to schedule final design mapping by aerial photogrametric methods during September or October of 1966.

PLATE I

COST SUMMARY OF ALTERNATE ALIGNMENTS

RECOMMENDED ALIGNMENT IS SHOWN THUS:

SUMMARY OF ALTERNATE ROUTES

WEST PORTION - V1 to V4 or H1-H4

A - Hill Route (H1-H2-H3-H4)
B - Route Via Mill Creek Connection (V1-V2-V3-H3-H4)
C - Valley Route (V1-V2-V3-V4)

EAST PORTION - V4-V8 or H4-H8

D - Hill Route (H4-H5-H6-H7-H8)
E - Route Via Thurmond Coulee Connection (V4-V5-V6-H6-H7-H8)
F - Route Via Sand Creek Connection (V4-V5-V6-V7-H7-H8)
G - Valley Route (V4-V5-V6-V7-V8)

ALTERNATE ALIGNMENT COST SUMMARY

(Combination of East & West Route Alternates Into Overall Alternate Alignments)

ALTERNATE ALIGNMENT DESIGNATION	TOTAL LENGTH IN MILES	TOTAL INITIAL COST	TOTAL ANNUAL COST
AD	21.18	$6,157,900	$4,223,400
AE	21.18	6,106,800	4,218,800
AF	21.32	6,105,000	4,245,400
AG	21.28	6,334,100	4,252,100
BD	21.24	6,096,800	4,228,500
BE	21.24	6,045,700	4,223,900
BF	21.38	6,044,000	4,250,500
BG	21.34	6,273,000	4,257,300
CD	21.16	6,170,500	4,219,400
CE	21.16	6,119,500	4,214,900
CF	21.30	6,117,700	4,241,400
CG	21.26	6,346,700	4,248,200

NOTE: 1. Cost figures have been rounded to nearest $100.00

2. The total initial cost is the initial project construction costs including right-of-way and related items.

3. The total annual cost is the sum of the annual costs for construction, maintenance and vehicle operation.

Purpose and Scope of This Investigation

This Geology study was made in conjunction with preliminary location design for the following purposes:

(1) To map in the field the general geological materials and conditions which would be encountered along the routes under study.

(2) To determine areas which may adversely affect highway design and furnish geological details where stability of slopes may be critical and sources of road bed materials are available.

(3) To furnish data pertinent to highway design in regard to field conditions at the site.

The scope of this reconnaissance precludes actual field drilling and laboratory testing.

Geography

This study includes that area along the Yellowstone River Valley from Pompeys Pillar to Custer, Montana. The area to the south of the Yellowstone River includes numerous tributaries. Sand Coulee, Mill Creek, Kaiser Creek, Spring Creek, Reed Creed, Automatic Creek, Bergum Coulee, Witham Coulee, Thurmond Coulee, and Sand Creek provide drainage from the higher benches to the south. The Huntley Project and Waco-Custer Irrigation Canals parallel the existing highway throughout the project. This mature river valley varies in width from one mile to 1500 feet along this nearly 21 mile project. Down cutting of the powerful Yellowstone River has left benches of resistant sandstone capping the adjacent foothills. Old meanders of the river are clearly evident. Tributaries to the Yellowstone River have notably marked the topography. Deep coulees have formed and erosional material in numerous alluvial fans is spread thickly along the coulee floors. Flood-plain deposits of silt, sand and clay make up the soil in the area. Gravels of river and glacial origin terrace the benches in many areas. Several terraces along the valley slopes are evidence of different stages of down-cutting throughout the river's history.

Geologic History

The sediments involved in the project area were deposited in South Central Montana during Upper Cretaceous time nearly 70 million years ago. During this time all but the western one-fifth of Montana was a sea shelf receiving marine deposition from seas transgressing southward. Western Montana was a large landmass of periodic uplift which supplied sediments eastward into the shelf area, thinning out in Eastern Montana. As much as 10,000 feet of sediment was deposited in a trough between this landmass and the marine shelf.

Cretaceous sedimentation was initiated by deposition of sandstones and conglomerates upon the eroded surface of older Jurassic sediments in the shallow sea. This was followed by deposition of the shale sequences of the Colorado Group. By Upper Cretaceous time the mountain building period had advanced far enough so that mountains appeared in Western Montana. As mountain building continued, the sea gradually withdrew. Folding and thrust faulting formed in the Western part of the State. Repetitive pulsations of uplift are recorded by interfingering of the Judith River and Horse Thief - Foxhills sandstones.

Subsequent deposition of shales and sandstones followed in this environment. The Bearpaw, Hell Creek, and Fort Union formations in the project area are remnants of this depositional pattern.

The withdrawal of marine waters marked the end of marine deposition and brought on a terrestrial environment. The marine sediments already deposited were slowly uplifted and eroded from the newly forming mountains to fill intermontane basins and spread eastward in an environment of flooded plains and swamps.

The great mountain building period of this time continued its uplift with increasing activity. Deformation of sediments followed and igneous activity, folding, faulting and erosion occurred along with stream and lake deposition until the topography became what it now appears.

The erosional pattern was formed from uplifting and is essentially the same now. The Yellowstone River and its tributaries have been actively cutting away the sediments through the project area since their natural paths were formed.

Sedimentary Features

The dominant sedimentary feature in the project area is the Hell Creek Formation. The Bearpaw Shale is known to underlie flood-plain deposits near the beginning of the project. However, it is not exposed in the project area. Quarternary deposits of gravel and alluvium are intermixed with flood plain deposits. Exposures of the Fort Union Formation exist on the higher ridges to the north and south of the project area.

The Hell Creek Formation is a fresh water deposit of alternating sandstone and clay shale. The association of interbedded sandstone and shale frequently affects their properties of strength and durability. Contact seepage often lubricates weak shale surfaces causing slides or building severe uplift pressures beneath relatively impervious beds. The lower portion of the Hell Creek Formation is exposed throughout the project. The bedding is relatively flat lying striking N15°E and dipping generally 4° to the east. Structural development to the South of the project caused uplift of the middle portion of the project area. The sediments dip slightly to the west toward the beginning of the project and to the east near the end of the project. Minor folding accompanied the uplift pressures. Several normal faults were observed south of Station 660 on the Valley Alternate but do not appear to affect the project alignments.

The development of soils in the area varies with topography. The high benches have a thin soil cover with numerous outcrops of Hell Creek sandstone. Accumulation of slope debris is evident in the larger coulees and presents problems of potential settlement within the confines of fill sections. The soils are derived from shales and soft sandstones of the Hell Creek Formation. Gravel deposits are intermittent throughout the project and it is suspected that the gravel is as much as 50' thick in some areas.

Subsurface drainage in and along the benches appears to be good. The lowland soils have low permeability resulting in poor surface drainage. Subsurface drainage along the Valley Alternate is generally fair. Drainage is complicated by the complex irrigation system present.

The material in the major cuts on the Hill Alternate and Valley to Hill Connections will make satisfactory embankment. The natural angle of repose is approximately 1-3/4:1; however, the interlayering of sandstone and shale enhances undercutting. Rockfall would be a problem in any portion with slopes steeper than 1-1/2:1. Shale Stability Design must be used as a guide to cut slopes.

Effects of Geology on Engineering Design

The scope of this reconnaissance precludes actual field drilling and laboratory testing although drilling and lab testing was accomplished by the Montana Highway Department in several areas of concern during the preliminary project investigation. In final design it is recommended that extensive examination be made in the areas of larger coulees where gumbo silts and clays have accumulated. It is anticipated that problems of consolidation in large fill sections will occur in these areas where the subgrade is thick gumbo soil. The fill sections should be designed after full evaluation is made of consolidation and shear analysis of the soil.

The cut sections throughout the project should be based on shale design criteria, although some cuts will be in sandstone. The effect of interlayering requires shale design of 2:1 backslopes. It is suspected that the sandstone is crusted hard where exposed and is relatively soft and moist where covered with gravel and topsoil.

The Valley Alignment (See Pictorial Maps, Fig. 45-76 for Stationing Layout)

Segment V1 to V4 (Station 0 to 420) This route nearly parallels the existing highway. It passes over Flood-plain deposits of silt sand and gravel along the valley floor. Deposits of river gravel from past meanders of the Yellowstone River are noticeable. Alluvial clays of local origin will be encountered near Stations 240, 260 and 370. Poor surface drainage is evident in these lowland soils due to apparent low permeability of the soils. Subsurface drainage is generally fair, however, it is complicated by complex irrigation throughout the valley. It appears there will be a slight cut section at Station 255.

Segment V4 to V5 (Station 420 to 465) This section passes over an old river channel. The channel change has left water in the area. Fill into this channel will require subsurface drilling and testing data. It is recommended that several test holes be drilled between stations 420 and 460.

(Station 465 to 500) - This area involves many cuts and fills in rugged terrain. The erosional products investigated in the coulees are predominately gumbo clays and silts immediately overlying sandstone. Several cuts will be in rather hard andesitic sandstone, although the entire cut section will contain alternating beds of soft interlayered shale and claystone. Cut and fill slopes at 2:1 can be used in this section due to the apparently good foundation of massive sandstone underlying the benched area.

(Station 500 to 550) - This section transverses a rolling bench cut by a rather wide drainage. From Station 505 to 523, a gravel bed underlies the topsoil and appears to average about 8 feet in thickness. No foundation problem is evident here. However, across the drainage coulee from Station 523 to 535 thick beds of gumbo clay mixed with gravel will necessitate removal of as much clay as possible in transition from cut to fill.

(Station 550 to 680) - This section passes over lowland flood plain deposits. The same conditions prevail here as in Station 0 to 420.

(Station 680 to 720) - This section consists of rather rugged terrain. Again the cuts will be in sandstone and alternating shales, with fills over gumbo clay erosional material.

Segment V5 to V7 (Station 720 to 880) - This area nearly parallels the existing highway along the valley floor. No apparent foundation problems are indicated.

Segment V7 to V8 (Station 880 to 910) - This section traverses along a bench cut by drainage gulches. The coulees contain thick beds of alluvial clays, silts and gravel and is typical of the soil pattern throughout the project. Cuts will be in sandstone and laminated shales. Fills will be predominately on gumbo material. Consideration of clay removal must be made in transition from cut to fill.

(Station 910 to 1123+74) - (End of Study) - This section traverses the valley floor and hills at the end of study. It presents no apparent foundation problems.

In summary the valley alternate mostly traverses the valley floor. The material originating in the major cuts will make satisfactory embankment. Fill slopes in drainages along the higher benched areas present the most troublesome design feature due to the accumulation of alluvial clays, silts and gumbo material. The Hell Creek Formation is nearly flat lying and the sandstone beds range in thickness from 1' to 30'. The interlayered shales erode easily and a typical section in this formation assumes a stable slope at approximately 1-3/4:1. Although some of the cuts will be in hard sandstone, Shale Stability Design criteria must be used or methods of controlling rock fall as a safety precaution. No evidence of a geological nature was found which would preclude using the Valley Alternate.

The Hill Alternate (See Pictorial Maps Fig. 13-44 for Stationing Layout)

Segment H1 to H2 (Station 0 to 140) - This section crosses the valley floor upon lowland soils of flood-plain origin and banks of river meander. Drainage is fair in this section although complicated by irrigation canals. There does not appear to be a foundation problem in this section.

Segment H2 to H3 (Station 140 to 260) - The Hill alignment leaves the valley near Station 140 and passes onto a bench area which is cut by two major drainages, Sand Coulee and Mill Creek. Several smaller coulees intersect the route in this section. From Station 160 to 187, a cut and fill section on a rising grade line in relatively soft basement material requires consideration of gumbo clay removal. From Station 187 to 240 in this section the route is upon relatively flat benched terrain capped by numerous gravel lenses underlain by thick sandstone. The Mill Creek drainage from Station 240 to 260 will require consideration of gumbo clay removal due to the accumulation of thick beds of erosional clays and silts for foundation. Consideration of removal of as much of this soft material as possible should be made in the transition from cut to fill.

Segments H3 to H5 (Station 260 to 290) - Station 260 to 290 traverses a benched area similar to the section from Station 187 to 240.

(Station 290 to 390) - Station 290 to 390 passes through numerous cut and fill sections. A typical section in this area will involve 2 feet of clayey topsoil, 2 feet to 5 feet of Course Gravel, 4 feet of tan, soft, shaley sandstone, 8 feet to 12 feet of massive light brown, hard sandstone underlain by 20 feet - 30 feet of shale and clay beds. The erosional material from a typical section like this is primarily a thick gumbo clay spread out in small alluvial fans, reworked by river and flood action and attaining thicknesses as much as 20 feet. A spring is noted at Station 340.

(Station 390 to 420) - This area crosses the valley floor to the old channel change and presents no apparent problems.

(Station 420 to 450) - The route enters the old river channel and is of special concern from a foundation standpoint. Fills along this section will be partially into the old river channel which contains water and partially onto thick accumulations of soft gumbo clay in the main drainage from the South. Several test holes should be drilled in this area to determine the depth of gumbo clay and its consolidation characteristics. The fill section design should be based on test results. The Hill Alternate joins the Valley Alignment near the end of this section.

Segments H5 to H8 (Station 710 to 765) - This alternate leaves the valley alternate at Station 708 ≠ 36 and enters on rugged terrain near Station 765. Some alluvia material has accumulated in small fans from Station 720 to Station 740.

(Station 765 to 900) - This section of the hill alignment crosses the most rugged terrain involved in the project. Deep gorged coulees filled with soft gumbo clay contrast with high cuts into hard sandstone immediately underlain by pervious waterbearing shale and sandy beds. Rapid erosion of shale and sand beds have left caps of hard sandstone protruding out over the coulees inviting rock fall, which is in evidence.

(Station 900 to 1118+49) - The material in this area of the project is higher in the geologic section of the Hell Creek Formation and is composed largely of massive sandstone underlain by predominately sandy sediments which are water bearing. In topography this is seen as low sandstone foothills. Numerous gravel deposits persist along higher benches. The topsoil in the lower areas is thinner and accumulation of gumbo material in the smaller gulches is considerably thinner and contains more sand fill.

In summary the Hill Alternate traverses rugged terrain for excavation purposes. Cuts will be in medium to hard sandstone grading down section to soft layered shale and sand clay beds. Fills will be upon relatively poor foundation in gullies and drainage areas where shale erosional products have accumulated. Excavation may disclose areas where additional drainage problems will be encountered. No geological evidence was found which would preclude using the Hill Alternate provided the recommended cut and fill criteria is used in the design or method of controlling rock fall are used as a safey precaution.

The Connection Segments

V3 to H3 - Mill Creek Connection (see Fig. 77-80)

V6 to H6 - Thurmond Coulee Connection (see Fig. 81-84)

V7 to H7 - Sand Creek Connection (see Fig. 85-89)

Segments V3 to H3, V6 to H6 and V7 to H7 connect the Valley Alternate with the Hill Alternate at chosen points. In all three cases they traverse lowland soils and climb in grade onto benched areas through narrow coulees as access. In the transition these routes will encounter three separate foundations (1) the lowland flood-plain silts (2) the alluvial gumbo (3) the sandstone and shale capped benches The flood-plain deposits present no particular problem. The alluvial gumbo upon which the rising grade line will be filled will require consideration of topsoil removal in transition from cut to fill Entrance onto the bench cuts must be made into the sandstone and interlayered shale.

Segments V6 to H6 crosses a deep coulee at Station 880 on the Hill Alternate. Accumulation of slope debris here appears to be thick.

None of these connections present a serious problem from a geological standpoint.

As in final design, for other Alternates discussed above, a detailed program of subsurface investigation and material testing should be initiated to determine the exact soil properties of these materials and the results of this investigation should be incorporated in the final construction plans.

Geological Exhibit Explanation

The geologic exhibit on Figures 5 through 8 relates the topography and geology to the studied alternates. The boundaries of the various geologic units are approximate and in keeping with the map scales. The boundaries between the River Flood-plan Deposits and Alluvium are arbitrary The materials interfinger and no attempt was made to accurately establish this transition

River Flood-plain Deposits - This is the material deposited in the Yellowstone River Valley adjacent to the channel. This portion of the valley is built of Flood-plain deposits of clay, silt and sand largely derived by overflow of the river at floodstage. Thick deposits of gravel underlie these flood-plain deposits at varying depths and are thought to be of glacial origin. Bedding is irregular with numerous gravel lenses paralleling the river.

Alluvium - This material is found fanning out from all the drainages to the south and consists of erosional silts and clays of local origin and termed gumbo. It is derived from the interlayered beds of the Hell Creek Formation and has accumulated in great depth at the base of most coulees.

The Bearpaw Shale - This formation is a light to dark grey marine shale with numerous calcareous concretions. It is known to underlie the Hell Creek Formation at the west end of the project, although it is not exposed in the area. It is not anticipated that this formation will be exposed upon drilling or excavation.

The Hell Creek Formation - This formation is a fresh water deposit of alternating Sandstone and Clay-Shale. It makes up the predominant topography of the project. The lower section of this formation is exposed throughout the project and all major cuts will be made in this material. A typical section is included in this report. Approximately 300 feet of the formation is exposed.

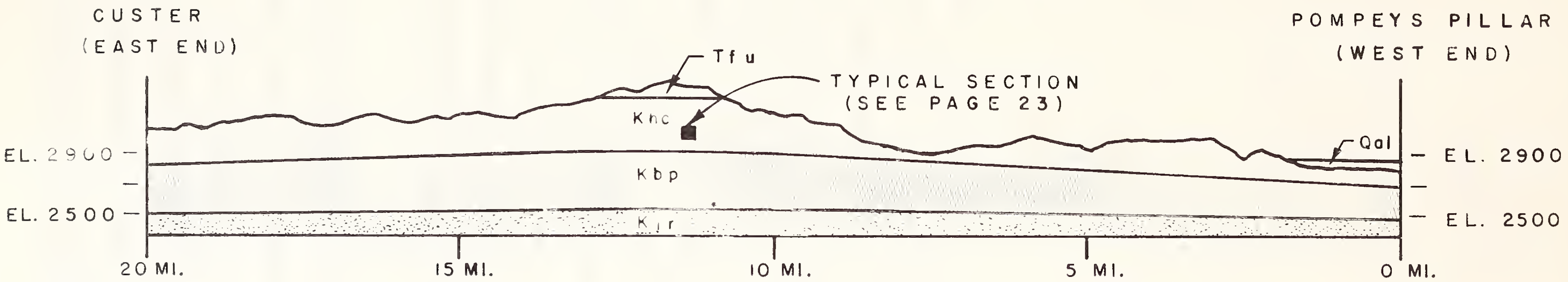
For Union Formation - This formation contains predominately dark clay and sand beds with ferruginous concretions and lignite beds. This formation also contains coal beds. It is exposed south of the project alignments and will not affect any alternates.

Gravel Terraces - This material is distributed intermittently throughout the project and varies in thickness from 1 foot to 20 feet as seen in exposures. It is in evidence in existing roadway cuts. Deposition of these gravels has been primarily by glacial recession although redistribution by river and flood means is evident along the valley floor.

Methods of Investigation & Acknowlegements

The geologic map was prepared in the field with the use of an autoscreen print, scale 1 inch equals 1000 feet. Information gathered by field study was transferred to the Report Plan and thus reduced to final scale. Geologic names, petrographic descriptions and geologic concepts incorporated in this report were taken from USGS Bulletin 541, "Coal Resources" by Rogers, and Billings Geological Society Guidebook, "Central Montana, 1956." Comparison of design data by Montana Highway Geology Department on Columbus East-West and field comparison of the completed Interstate project along Hysham Hills in similar formations was used as a guide to slope design.

GENERAL GEOLOGIC PROFILE
CUSTER TO POMPEYS PILLAR



KEY

Qal	ALLUVIUM	0-50'
Tfu	FORT UNION FORMATION	200'
Khc	HELL CREEK FORMATION	300'-380'
Kbp	BEARPAW FORMATION	400'-600'
Kjr	JUDITH RIVER FORMATION	300'-600'

SCALE: HORZ. 1"=2.5 MI.
VERT. 1"= 1000'

TYPICAL SECTION
HELL CREEK FORMATION

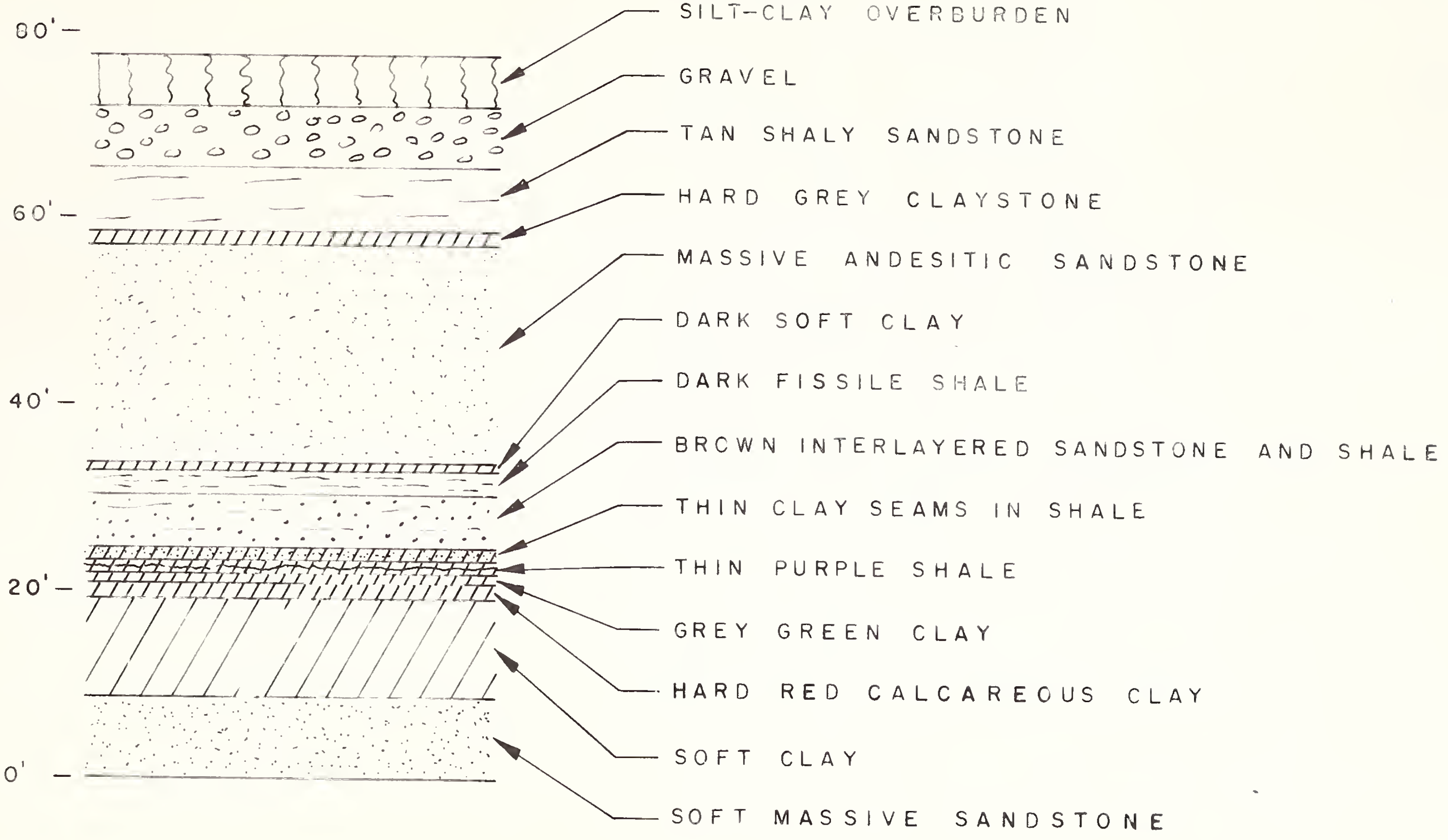
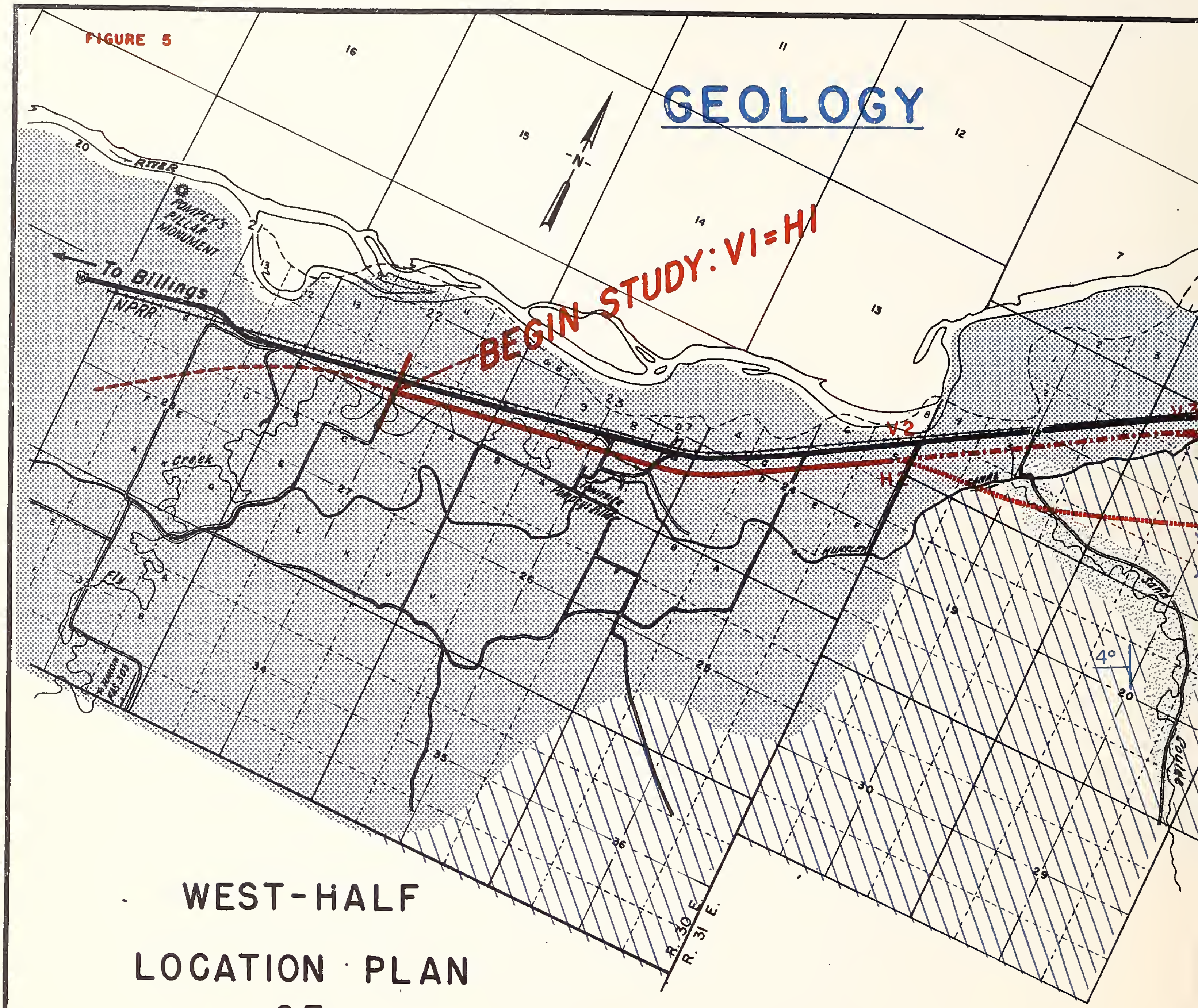


FIGURE 5

GEOLOGY



WEST-HALF

LOCATION PLAN OF ALTERNATES STUDIED INTERSTATE 94 POMPEYS PILLAR TO CUSTER

-LEGEND-

EXISTING

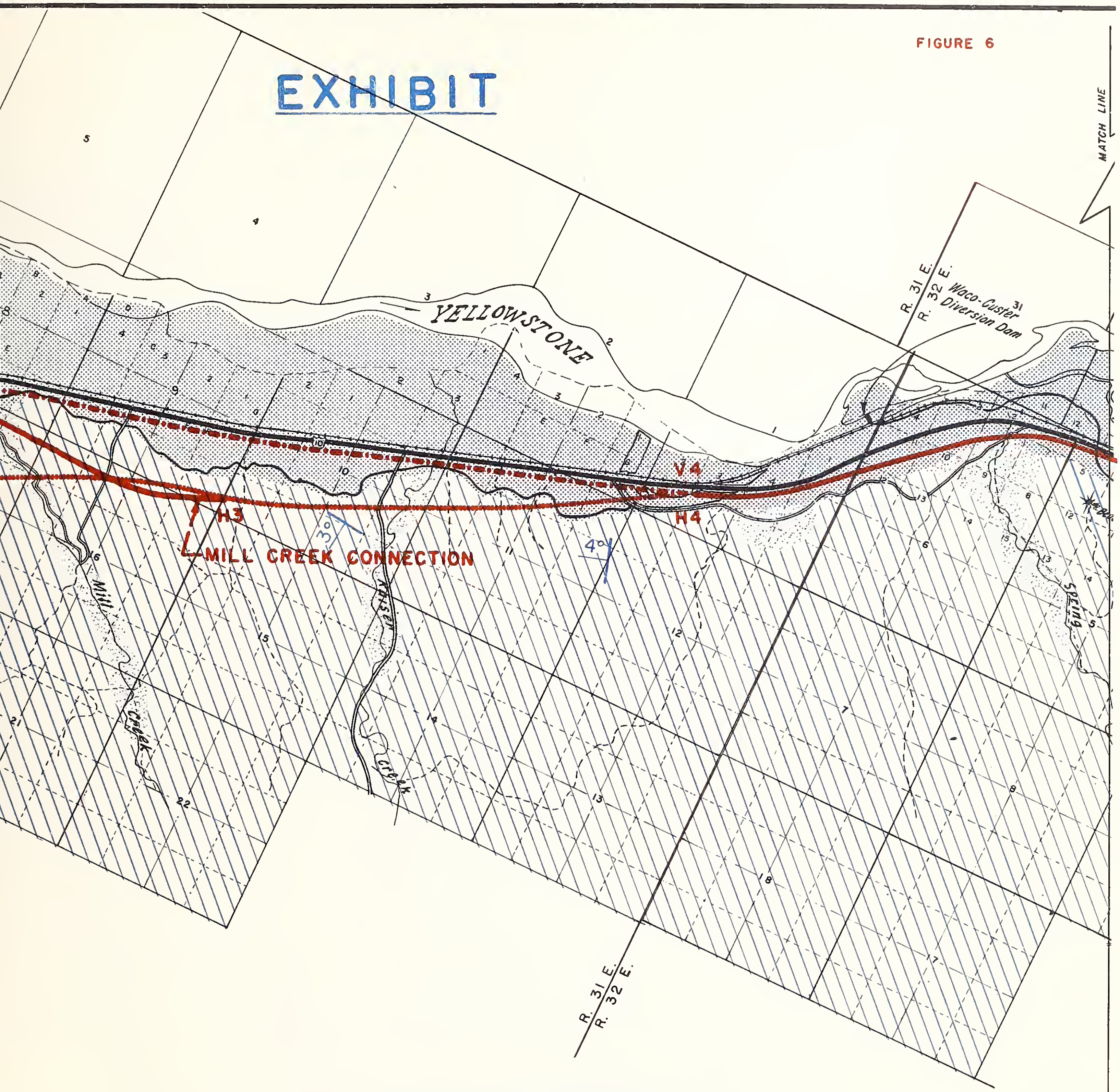
U. S. HIGHWAY 10	—10—
LOCAL ROAD	═
N.P. RAILROAD	+++++++++
STREAMS	—
IRRIGATION CANALS	━
TRAILS	-- -- --

INTERSTATE THIS STUDY

HILL ALTERNATE	·········
VALLEY ALTERNATE	-·-·-·-
CONNECTIONS AND COMMON ALIGNMENT (Hill & Valley)	━━━
JUNCTION DESIGNATION	V1 H1
(I-94) BY OTHERS	-----

FIGURE 6

EXHIBIT

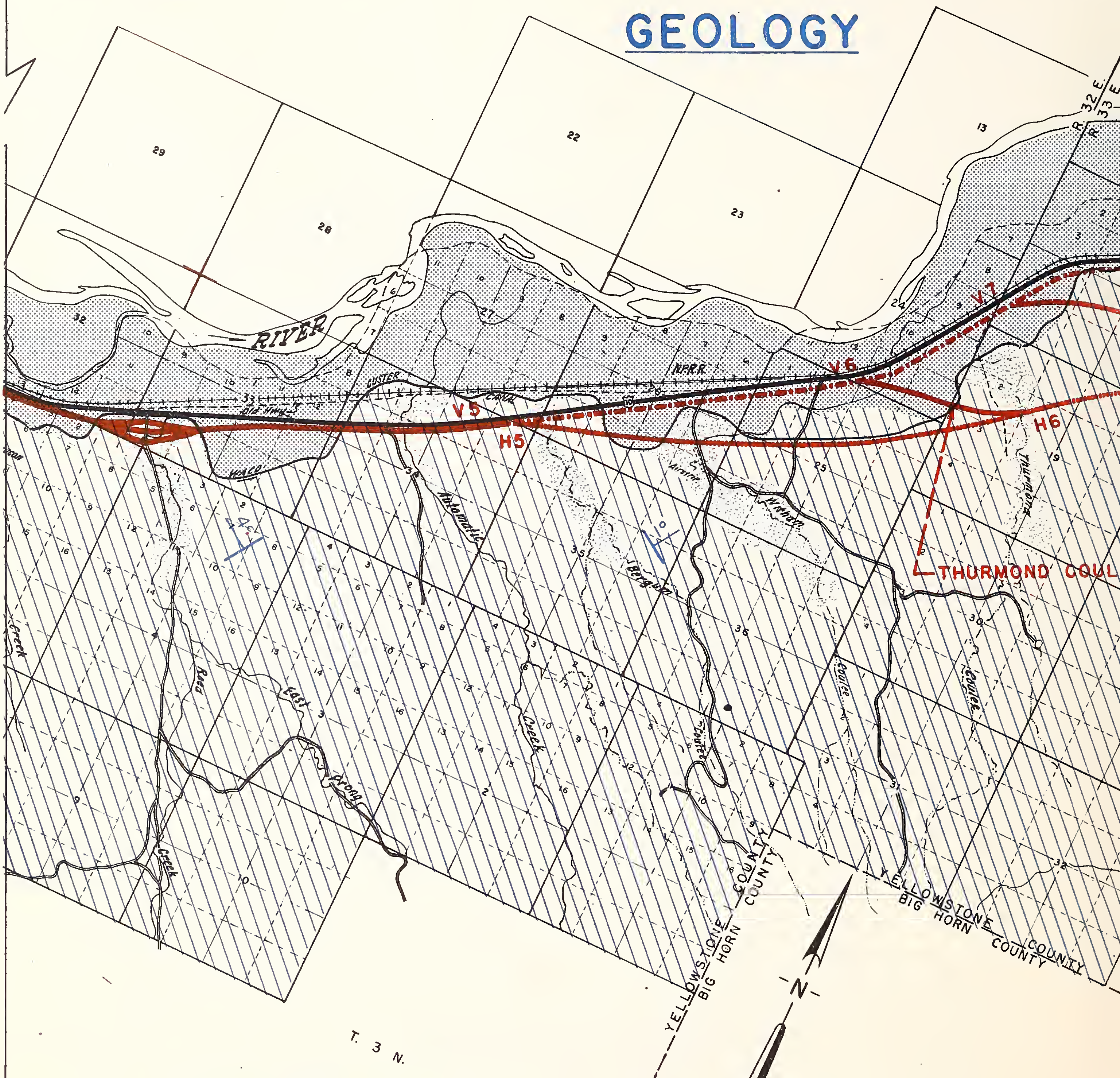


GEOLOGY EXPLANATION

▩	FLOOD PLAIN DEPOSITS. TRANSPORTED SILT, SAND, GRAVEL & CLAY LARGELY DERIVED BY OVERFLOW OF THE YELLOWSTONE RIVER AT FLOODSTAGE. BEDDING IS IRREGULAR WITH NUMEROUS GRAVEL LENSES.
░	ALLUVIUM. THIS MATERIAL IS FOUND FANNING OUT FROM ALL DRAINAGES AND CONSISTS OF EROSIONAL SILTS AND CLAYS, LOCALLY TERMED GUMBO. IT IS DERIVED FROM INTERLAYERED BEDS OF THE HELL CREEK FORMATION.
▧	HELL CREEK FORMATION. A FRESH WATER DEPOSIT OF ALTERNATING SANDSTONE AND CLAY SHALE, FORMING THE DOMINANT TOPOGRAPHIC BENCHES CAPPED BY RESISTANT ANDESITIC SANDSTONE. (SEE TYPICAL SECTION)
⊣	DIP AND STRIKE OF SEDIMENTS.

FIGURE 7

GEOLOGY



GEOLOGY EXPLANATION

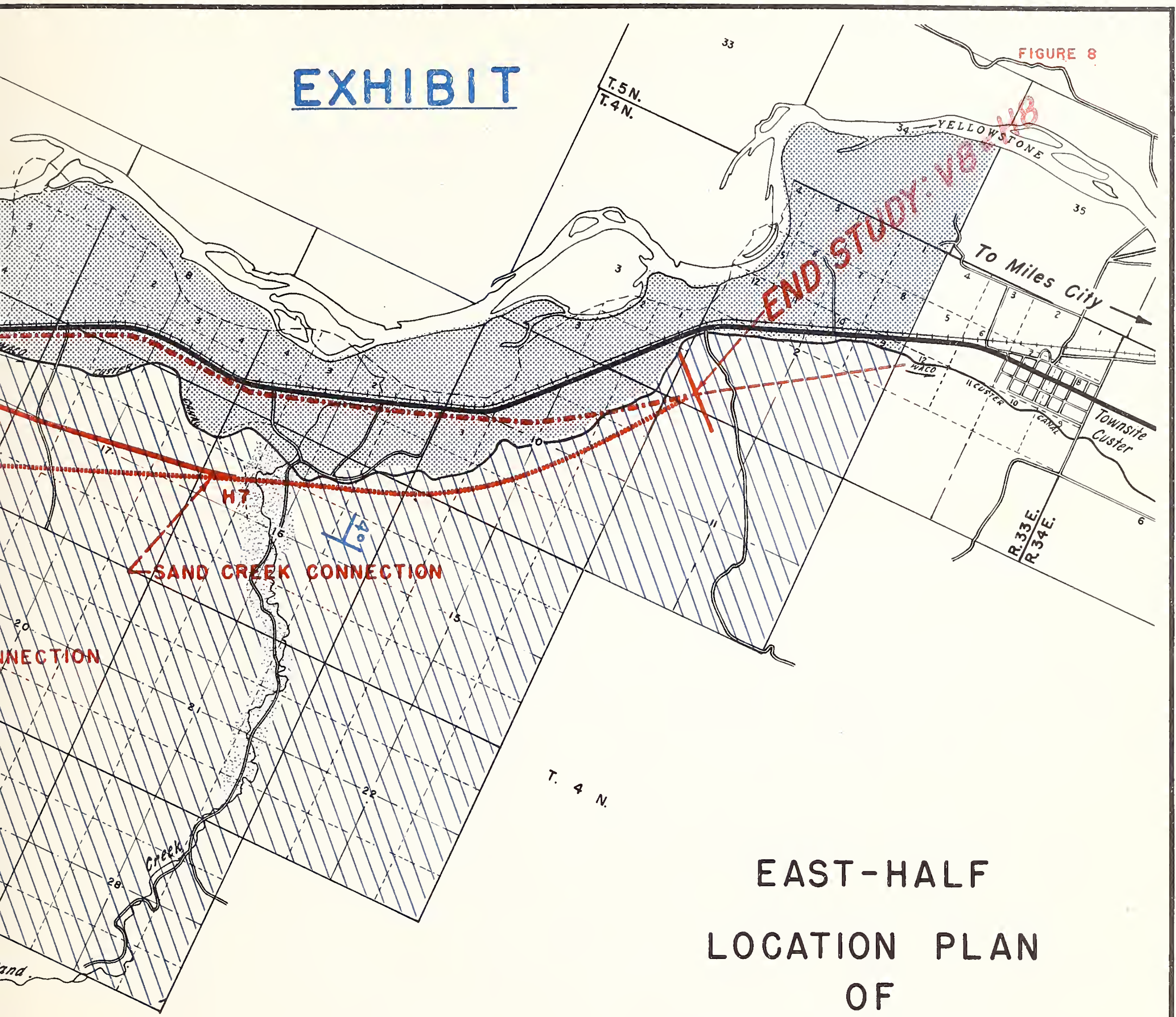
▩ FLOOD PLAIN DEPOSITS. TRANSPORTED SILT, SAND, GRAVEL AND CLAY LARGELY DERIVED BY OVERFLOW OF THE YELLOWSTONE RIVER AT FLOODSTAGE. BEDDING IS IRREGULAR WITH NUMEROUS GRAVEL LENSES.

░ ALLUVIUM. THIS MATERIAL IS FOUND FANNING OUT FROM ALL DRAINAGES AND CONSISTS OF EROSIONAL SILTS AND CLAYS, LOCALLY TERMED GUMBO. IT IS DERIVED FROM INTERLAYERED BEDS OF THE HELL CREEK FORMATION.

▧ HELL CREEK FORMATION. A FRESH WATER DEPOSIT OF ALTERNATING SANDSTONE AND CLAY SHALE, FORMING THE DOMINANT TOPOGRAPHIC BENCHES CAPPED BY RESISTANT ANDESITIC SANDSTONE. (SEE TYPICAL SECTION)

⊣ DIP AND STRIKE OF SEDIMENTS

MATCH LINE



EAST-HALF

LOCATION PLAN OF ALTERNATES STUDIED INTERSTATE 94 POMPEYS PILLAR TO CUSTER

-LEGEND-

INTERSTATE THIS STUDY

HILL ALTERNATE	••••••••
VALLEY ALTERNATE	–·–·–·
CONNECTIONS AND COMMON ALIGNMENT (Hill & Valley)	——
JUNCTION DESIGNATION	V1 H1
(I-94) BY OTHERS	-----

EXISTING

U. S. HIGHWAY 10	—10—
LOCAL ROAD	═══
N. P. RAILROAD	┼┼┼┼┼┼┼┼
STREAMS	——
IRRIGATION CANALS	——
TRAILS	- - - -

HYDRAULICS AND DRAINAGE

All I-94 alternate alignments studied herein cross several natural drainage channels which drain land south of the Yellowstone River and, in general, run northerly to discharge into the river. All but Fly Creek are normally dry streambeds except at times of snow melt or severe storms involving stormwater run-off from the dry land area south of the irrigation canals. Most of the drainage areas involved in this study is either grass covered or devoted to dry crop agriculture and have little tree cover. Below the irrigation canals these creek channels collect waste irrigation water which they convey to the river during the irrigation season.

The size and type of structure selected for each situation are shown on the Plan-Profile sheets. For this preliminary design and cost estimate, the design tables and procedure set forth on pages 62-68 of "Field and Office Standards" have been used except for Fly Creek, Sand Coulee, Kaiser Creek and Reed Creek on which the drainage areas exceed the range covered by these design tables. For these larger drainage areas, the Burkli-Ziegler formula $(Q=MRc\ \frac{S^{\frac{1}{4}}}{M})$ has been used. These tables used are for a 25 year storm intensity of 1.30 inches per hour. To convert to 50 year storm intensity the discharge values from "Field and Office Standards" were multiplied by 1.2 for quantities on which to base culvert sizes as shown on Plan-Profile sheets and as covered by the cost estimates in this report. For Fly Creek the use of this formula may very well be more conservative than is necessary because the design storm intensity would likely not cover the whole area with a uniform intensity. On final design, a more thorough analysis and more realistic design procedure will be employed with the development of a discharge curve for the Fly Creek drainage area using staff gaging reports and other data as collected by the U.S. Geological Survey and Montana State Highway Commission. However, for the purposes of this study, the results obtained by use of the Burkli Ziegler formula do not appear overly conservative when judged by the existing highway bridge that carrys the P.T.W. over Fly Creek. For this study, bridges have been used at the County road and I-94 crossings of Fly Creek. Structural Plate Culverts are proposed for all other large drainage structures. These Fly Creek bridges are discussed further under a subsequent section of this report entitled, "Major Underpass and Drainage Structures".

As has been stated above, structural plate culverts have been estimated for most major drainage channels even though these culverts may be located immediately upstream from an existing treated timber bridge on the P.T.W. It has been judged that structural plate culvert (SPPC) will provide an adequate and satisfactory structure for I-94 and for the south frontage road except for Fly Creek. Undoubtedly when the old timber bridges were constructed, structural plate pipe culverts were not in general use and the standard timber bridges were used even though they may have provided overly conservative drainage capacity.

At certain locations, the available contour map data and field examination does not fully reveal just how drainage is adequately taken care of under the present highway. For example, at Reed Creek the existing culvert is substantially smaller than would be required on the basis of design standards set forth for this study. Drainage must now be taken care of through diversion via the Wacd-Custer irrigation canal as well as by some ponding to allow the Reed Creek culvert time to carry the design storm run-off away. On final design situations of this nature will be studied thoroughly to arrive at the most adequate and satisfactory solution of this problem. It is believed that the estimated cost of the drainage structures, shown on the Plan Profile sheets, will budget sufficient money for the system of drainage pipes required although on final design, method, location and size may be subjected to some variation from that proposed in this study. Drainage culverts smaller than 60" for I-94 and frontage roads have been estimated on the basis of an average cost per mile. This per mile cost has been established after a cost appraisal of the existing system of these smaller culverts under the PTW. Drainage cost estimates include an allowance to cover such culvert incidental costs as headwalls, select bedding material and culvert excavation.

DESIGN STANDARDS AND CRITERIA

General

Design criteria for this study have been based on those acceptable for construction of Interstate Highways. This policy is outlined in the pamphlet entitled, "Geometric Design Standards for the National System of Interstate and Defense Highways" as adopted by the American Association of State Highway Officials (A.A.S.H.O.) and the U.S. Department of Commerce, Bureau of Public Roads. This is the criteria used on Interstate Highways throughout the Nation. The following books and publications were also used as design guides:

A.A.S.H.O. Publications:

- Policy on Geometric Design of Rural Highways
- Road User Benefit Analysis for Highway Improvements
- Highway Capacity Manual

M.S.H.C. Publications:

- Standard Specifications for Road and Bridge Construction
- Field and Office Standards
- Standard Drawings

Design Factors:

(1) Type of Terrain-Flat and Rolling

(2) Design Speed - 70 M.P.H.

(3) Traffic Lane Width - 12 feet

(4) Traffic Data (From Montana Highway Commission Planning Survey Division)

West Portion of Study (V1-H1 to V4-H4)

Average Daily Traffic, 1962 -------------------- 1353 (ADT)

(Number of Vehicles) 1975 -------------------- 3250
1990 (Design Year) -------- 4850

Commerical Vehicles as % of ADT ---------------- 14.3%

Design Year Hourly Volume (1990 DHV) ------------ 630 vehicles

Commercial Vehicles as % of DHV ---------------- 11 %

East Portion of Study (V4-H4 to V8-H8)

Average Daily Traffic, 1962 1329 (ADT)

(Number of Vehicles, 1975 3200
1990 (Design Year) 4750

Commerical Vehicles as % of ADT 14.3%

Design Yearly Hourly Volume (1990 DHV) 620 vehicles

Commerical Vehicles as % of DHV 11%

* (5) Number of Traffic Lanes - Two initial with R/W provision for future expansion to Four Lanes

(6) Typical Roadway Section - See Figure 9

Roadway Design

The typical section used in this study is illustrated on the drawing entitled, "Typical Highway Section". It is bound at the end of this section and is identified as Figure 9.

The pavement section of the initial two lane facility is planned for two 12-foot traffic lanes and 10-foot shoulders. In studying Interstate location relative to the P.T.W. and other physical features and conditions it has been assumed that the future width between east and west bound pairs of traffic lanes will be 100 feet center to center.

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*See "Capacity/Traffic" sub-section on page 30.

The west bound pair of traffic lanes is proposed for construction as the initial two lane facility. This is in consideration of such factors as the likely source of borrow material and aggregates for pavement base and surface courses as coming from the hills to the south of the PTW. Thus in the future it is less likely that the west bound lanes will cut off construction of the east bound lanes from sources of borrow and aggregate than if the east bound lanes are constructed initially..

The typical section indicates the method of widening to maintain 2300 foot passing sight distance on circular curves where widening is required.

The Geology section of this report describes the material through which this highway must be constructed. For backslope purposes much of this material possesses inferior stability. Sloughing of the backslope can be expected as weathering occurs regardless of the angle of backslope. The cut slope design recommended, not to exceed 2:1, is in consideration of the fact that even what may appear to be solid sandstone is usually interlaying with shale seams. This condition will enhance undercutting and cause rock fall if steeper than 2:1 cut slopes are used.

Excavated material will make suitable material for embankment constrution for the fill slopes shown on the Typical Section, provided that compaction and other construction methods are proper and adequate.

Spiral transitions will not be required on the ends of horizonatal curves in this study area because no degree of circular curve exceed $1^{\circ}15'$. The rate of superelevation will not exceed 0.08 of a foot per foot. This is based on considerations of such factors as climatic conditions, terrain and the frequence of slow moving vehicles. Transition to an from full superelevation will be provided for in a runoff distance beyond the beginning and end of all circular curves.

All sections of Interstate Highway under this study have been designed for 2300 foot passing sight distance including length of crest vertical curves. Crest vertical curve lengths have been established as per criteria specified for standard heights of eye and sighted vehicles as established by A.A.S.H.O. Thus 70 MPH design has been maintained throughout for this two lane Interstate facility. These lengths of vertical curves can be incorporated into the design without excessive earthwork costs. They do enhance the problem with long deep "trench" sections when transitioning in grade from valley elevation to plateau elevation as has been previously discussed but maintaining 70 MPH design throughout as a safety measure has been judged to be paramount. This is in consideration of the fact that, coming from the west, this highway is immediately adjacent to four lane facilities where the driver will have gotten used to a 70 MPH road. Furthermore the driver would not expect less than a 70 MPH road in this part of the State and to design for a lesser speed would introduce a traffic hazard.

In keeping with 70 MPH design criteria all Interstate longitudinal gradients have been maintained at 3% or less. In the following section on "Geometrics and Location", on Plate 2 at the end of said section, gradient and curve data has been summarized in table form.

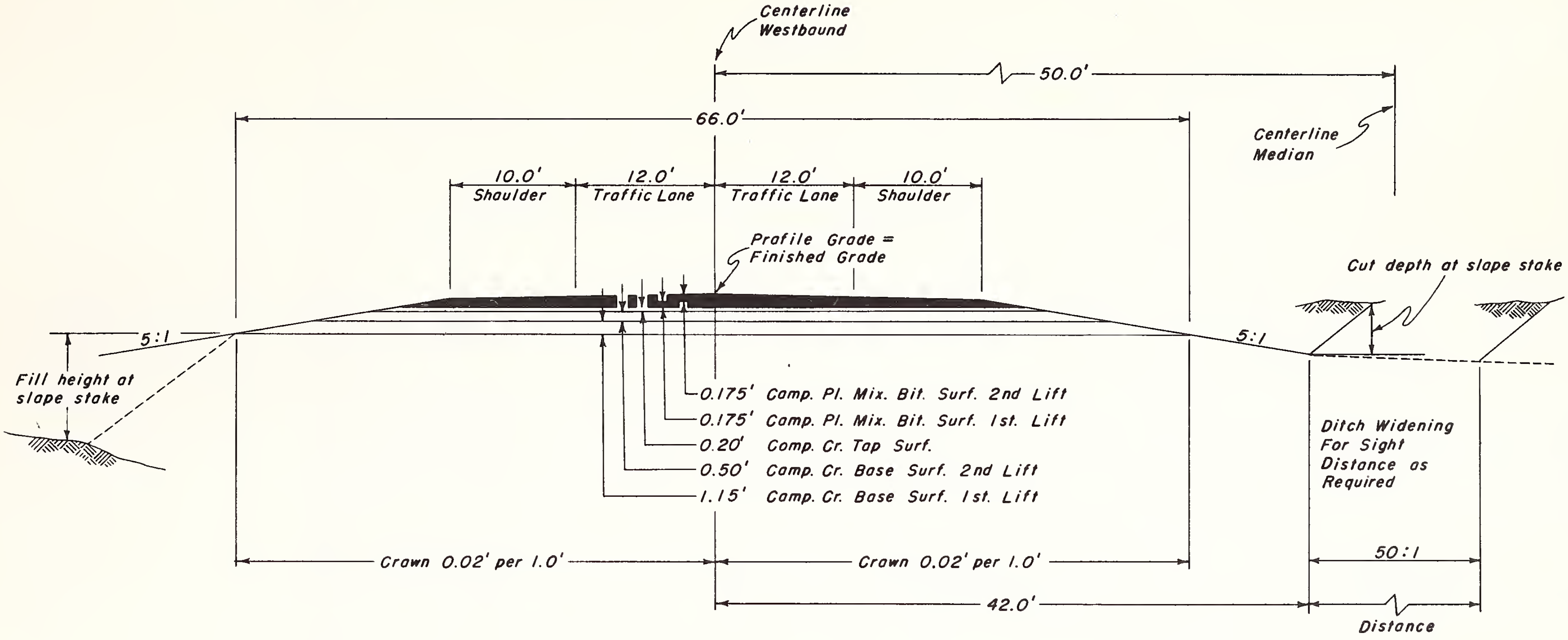
Capacity Traffic Considerations

In calculating the design capacity of this two lane Interstate Highway one must start with a running speed of 40-45 MPH as has been established by Bureau of Public Roads' directive for design in rural areas. This directive further states that, "in calculating the design capacity on a particular section the calculation should follow the Highway Capacity Manual beginning with a design capacity of 900 passenger cars per hour;" the value for level tangent sections of two lane highway. With the 11% commercial vehicles, this 900 VPH would be reduced to approximately 790 VHP. On page 94 of the 1965 Highway Capacity Manual, 1,500 feet has been defined as the minimum sight distance, from eye height of the driver to that point where the top of an approaching car first comes into view, at which no reduction in capacity occurs. Since this highway is proposed to be designed for 2,300 foot passing sight distance throughout, including all circular and vertical curves, there is no reduction in capacity due to sight distance being restricted to less than 1,500 feet. Thus, on level sections of this highway, the 790 VPH design capacity is substantially higher than the 630 DHV (design year) of the westerly portion of this highway and the 620 DHV (design year) of the easterly portion. Grades would tend to reduce the design capacity below 790 VPH but the grades proposed herein would not effect a reduction anywhere near the difference between 790 VPH and 630 VPH. Because design capacity on all sections of this highway is greater than 630 VPH, no more than the two traffic lanes can be justified.

FIGURE 9

— BACKSLOPES —

Cut or Fill Depth	0'-5'	5'-10'	10'-15'	Over 15'
Cut or Fill Slope	5:1	4:1	3:1	2:1


Centerline Westbound
50.0'
66.0'
Centerline Median
10.0' Shoulder
12.0' Traffic Lane
12.0' Traffic Lane
10.0' Shoulder
Profile Grade = Finished Grade
Cut depth at slope stake
5:1
5:1
Fill height at slope stake
0.175' Camp. Pl. Mix. Bit. Surf. 2nd Lift
0.175' Camp. Pl. Mix. Bit. Surf. 1st. Lift
0.20' Comp. Cr. Tap Surf.
0.50' Camp. Cr. Base Surf. 2nd Lift
1.15' Camp. Cr. Base Surf. 1st. Lift
Ditch Widening For Sight Distance as Required
Crown 0.02' per 1.0'
Crown 0.02' per 1.0'
50:1
42.0'
Distance

— TYPICAL ROADWAY SECTION —

INTERSTATE 94 – POMPEYS PILLAR TO CUSTER

(2 LANE)

GEOMETRICS AND LOCATION

General

The area of study for this section of I-94 traverses the southerly side of the Yellowstone River Valley and the hills and plateaus which lie immediately south of the irrigated river valley. The terrain had a definite bearing on the selection of route alternates for study. Great care is required in getting a 70 mile per hour designed Interstate Highway up and out of the irrigated valley and from a route parallel to the P.T.W. onto the dry land plateau in the most efficient and economical manner and in a way that causes the least damage to the irrigated valley. Probably no phase of this study presented a greater challenge to the designer. Certainly the results of getting an Interstate Highway of 70 M.P.H. and two lane design standard from valley to plateau with minimum cost of earthwork are often disappointing when it comes to being able to minimize the undesirable grade situation where the highway is carried in a relatively deep cut section for considerable distances. This situation, and the need to seek the shortest possible route length so as to minimize road user costs, does preclude designing the most scenic highway possible. On all routes and grades studied, the designer has made a determined effort to minimize the "trench" section effect consistent with designing for the standards set forth in detail in the section of this report entitled, "Design Standards and Criteria" and for minimum cost which has been held as the paramount of all considerations.

PLATE 2

GEOMETRIC SUMMARY

Route Segment Designation	Length Miles	Average Grade %	Maximum Grade %	Percent Of Curvature	Average Degree of Curvature	Maximum Degree of Curvature	Total Horizontal Deflection
Hill Route - **West Half** H1-H2-H3-H4	8.48	1.19	3.00	45.49	0°42'	1°15'	141°37'
Mill Creek Route - V1-V2-V3-H3-H4	8.53	1.08	2.70	35.33	0°42'	1°00'	110°37'
Valley Route - **West Half** V1-V2-V3-V-4	8.45	0.55	2.70	12.62	0°50'	1°00'	46°57'
H4 - H5	4.94	1.81	3.00	54.14	0°49'	1°00'	114°12'
V4 - V5	4.94	1.81	3.00	63.96	0°42'	1°00'	117°15'
Hill Route - **East Half** H5-H6-H7-H8	7.77	1.46	2.70	43.90	0°34'	1°00'	103°05'
Thurmond Coulee Route V5-V6-H6-H7-H8	7.76	1.52	2.96	42.70	0°42'	1°00'	123°24'
Sand Creek Route - V5-V6-V7-H7-H8	7.91	1.18	3.00	45.56	0°41'	1°00'	131°07'
Valley Route - **East Half** V5-V6-V7-V8	7.86	1.08	2.64	27.63	1°06'	1°15'	125°30'

As discussed under the previous section, "Introduction", this study covers in detail various alternates for I-94 with twelve overall route possibilities, as shown in general on, "Location Plan of Alternates Studied" and covered in details as to geometrics and grades on "Plan-Profile" Sheets, Figures 13 through 89 bound at the end of this report.

Preliminary evaluation of prospective locations in the field and on topographic and aerial maps resulted in the decision to study in final detail and present herein the afore mentioned twelve route alternate combinations. Prior to this decision many other route possibilities were investigated in sufficient detail to determine that these other possibilities were not as economical and satisfactory as the route alternates presented herein. Some of the more noteworthy of these discarded possibilities are discussed, in general, later in this section.

A summary has been prepared to show the geometric features of each segment of each alternate. It is entitled, "Geometric Summary", Plate 2 and is shown on the opposite page.

Hereinafter, when Station references are given, it shall be understood that the tie is given only to the nearest even Station and thus not exact but at least as close as plus or minus 50 feet.

In the detailed discussion of each route alternate which follows local access facilities such as frontage roads and vehicular or stock underpasses are discussed with the section of I-94 with which they are closely related but drainage culverts are not mentioned in this section unless they serve a dual purpose; that is, have a noteworthy value as a stock pass as well as drainage structure. Rather all drainage facilities have been covered in the previous section on "Hydraulics and Drainage". Only Type 2 and 3 frontage roads are discussed in this study and shown on the Plan-Profile Sheets. Numerous dozer trails are anticipated for supplemental local access and an allowance has been made in the cost estimates for these facilities but showing them on these preliminary plans seems premature prior to actual right-of-way negotiations. Indeed it seems that possible public knowledge of such facilities could actually prejudice the right-of-way agent's position in negotiations with the land owners. For this same reason sizes of structural plate underpass structures, as sized for this study's cost estimates, are not shown on the Plan-Profile Sheets or discussed herein.

Grades and Earthwork

Alternate line and grade studies were made from photogrammetric reconnaissance maps furnished by the Montana Highway Department. The contours on these maps were at 4 foot intervals except where steep slopes required intervals of 20 feet. The scale of these maps is one inch equals 200 feet. Ground line profiles were plotted from these maps and the longitudinal grade studies were made on these profiles. Earthwork quantities were, in general, made by scaling cuts and fills of these profiles and then going to cut and fill end area tables which were made up for the typical roadway section. Where necessary, this earthwork determination procedure was supplemented with corrective factors due to substantial transverse slopes. In some areas, notably in areas of extreme sidehill slope conditions and where the I-94 section "daylighted" into an existing highway cut section, cross-sections were plotted and templated with the finished grade cross-section to determine earthwork quantities. In cut sections on circular curves where ditch widening was necessary to maintain 2300 foot sight distance, earthwork quantities were made to reflect these excavation quantities.

For the Hill Routes, beginning with H2 and extending continuously through to H8, grades were laid for balanced earthwork. Shrinkage factors were figured as per table on page 86 of "Field and Office Standards". On final design, if all or part of the Hill Route is selected, consideration will be given to the economics of a "balanced earthwork" concept versus raising some grades and borrowing for embankment outside of the roadway excavation section. It is conceivable that with knowlege gained from soil profiling and with the rock line thus defined, where rock is a factor, it may be possible to adopt the latter course at no greater an earthwork cost, that is, raising some grades to avoid rock excavation with borrow at strategic locations to "daylight" sidehill cut sections where practical. This would improve the Interstate traveller's chances to gain a view laterally and thus improve the scenic quality of the highway.

For the long stretches of the irrigated bottom land on the Valley Route, balanced earthwork will not be practical or desirable. Imported embankment material will be essential to avoid causing drainage problems and to build a stable highway grade in this irrigated land. Embankment material for this purpose has been assumed to come from the roadway excavation where the Valley Route traverses hilly terrain between irrigated valley sections or from the Hill Route between H2-H3 and V3-H3 to the extent that roadway excavation and haul is deemed to be more economical than going to a borrow pit outside the roadway section. Imported borrow seems to be a must for that section of I-94 west of V4 for the Valley Route, west of V3 for a routing involving the Mill Creek Connection and west of V2 for a Hill Route beginning at H2. It has been judged to be practical and feasible to obtain borrow material within reasonable haul distance south of the Town of Pompeys Pillar or from islands in the Yellowstone River bottom say immediately north of the Town. The latter location would have the problem of crossing the P.T.W. and Northern Pacific Railway tracks. Between the Rest Area site near Station 606 and V5, the grades shown in this report will require borrow in excess of 100,000 Cubic Yards. Such borrow could come from the hill in the vicinity of V5, perhaps from the right-of-way purchased for future I-94 four lane construction. Borrowing, within limits, from this future construction area would not cause a future earthwork problem because approach fills to this hill for a four lane facility would be substantially less than is required for two lane design. That is, passing sight distance for the two lane facility requires a substantially longer vertical curve than for a four lane facility where only stopping sight distance is required and the approach fill requirements are directly tied into this vertical curve situation. Borrow in the vicinity of V5 seems much more feasible from an earthwork cost standpoint than lowering the grade over this hill below that shown on Figures 64 and 65 inasmuch as sandstone is exposed on the cut backslope for much of this length of the P.T.W. The I-94 grade must be laid lower than the existing highway grade at the crest of the vertical curve to get the proper grade-vertical curve relationship required by I-94 design criteria.

Between V7 and V8 on the Valley Route a substantial amount of fill material can be obtained in the cut section between Stations 899 and 909 but embankment requirements will still leave a deficit to be made up from borrow. Either the Thurmond Coulee Connection or the Sand Creek Connection will involve haul out of the hills back into the valley to partially fill embankment requirements. In addition to the economics of haul of road excavation versus borrow, as far as these connection routes are concerned, it does not seem practical or desirable to lower grades over those shown between V6-H6 and V7-H7 to assist with the deficit on embankment between V5 and V7. To do so would only enhance the undesirable situation where the road must pass through relatively long deep cut sections to gain ascent from the valley floor to higher terrain. Indeed it is to be hoped that economically feasible ways and means can be found on final design to raise grades and thus reduce the length of cut sections.

At V8=H8 an earthwork balance point has been established for all alternates and thus this study area of I-94 is self sufficient without earthwork haul into or out of the section of I-94 east of this point. On final design, depending upon the routing approved, it may be desirable to study the earthwork picture integrally on either side of this rather arbitrarily chosen point and establish a different balance point.

V1=H1 to V2=H2

Discussing the location and geometrics of each segment of each alternate route in turn and beginning at the west end of this study area, reference should be made to Figures 13 through 16 for the corresponding Plan-Profile Sheets. From V1=H1, Station 0+00 for all alternates, the proposed alignment of I-94 would parallel the PTW with centerline of median location approximately 150 feet from centerline of the PTW. For the Valley Route where the Interstate alignment closely follows the PTW this 150 foot offset has been maintained, in general, except where the fill section for a grade separation structure or some other special situation dictates a slightly greater offset. Proceeding easterly toward the Town of Pompeys Pillar it will be necessary to construct several channel changes in Fly Creek to get this meandering stream out of the Interstate right-of-way. Relocation of the 8" Cenex fuel products pipeline alignment will also be required in this interval for the same reason.

At Station 59 a Type I reinforced concrete underpass is proposed to carry I-94 over the local country road. Hereinafter, when reference is made to Type I and Type II underpasses, the reference is to a reinforced concrete structure as per details, Figures 10 and 11, bound in this report with section entitled, "Major Underpasses and Drainage Structures." This underpass will serve as the access to the PTW to and from the Town of Pompeys Pillar and for traffic south and east of the Town. The PTW will in turn provide access to all points east and west of Pompeys Pillar now reached by U.S. Highway No. 10 and for local traffic to gain access to the Interstate at the interchange proposed approximately two miles west of Town. Since Fly Creek must be channel changed in the vicinity of this underpass to clear the Interstate and especially the approach fill section on the underpass, it will be necessary to construct a new county road bridge across Fly Creek between Town and the underpass. East of the underpass I-94 will cross Fly Creek on a new reinforced concrete bridge.

At Station 76 a south frontage road will begin at the present road leading into the Town from the east. From this point I-94 and the south frontage road will continue to junction point V2=H2 except that, for the Hill Route, the south frontage road discontinues at Station 142, it having provided access to a farm immediately to the east by having extended to this point.

V2=H2 to H3

This segment, covered by Plan-Profile Sheets, Figures 16 through 22, is the proposed alignment of I-94 which accomplished the transition from parallel to the PTW at H2 to the Hill Route via Sand Coulee. With a transition from Valley to Hill Route, it is necessary to cut through a productive irrigated meadow to reach non irrigated land. A direct alignment straight from the Town of Pompeys Pillar to H3 was thoroughly considered because of the shorter distance. When all costs including right-of-way were considered the H2-H3 routing is more economical than a "straight across" alignment from the Town of Pompeys Pillar to H3 on both initial and annual costs. A substantial part of this cost saving results from using the easterly side of Sand Coulee as a natural slope to assist in gaining the plateau level. Earthwork is thus substantially reduced over a straight across route.

Where I-94 crosses the Sand Coulee road at Station 180, a realtively important local access road, a Type II underpass structure is proposed to allow passage of the local road under the Interstate. Some realignment of this local road will be necessary to place the underpass at a point above the bottom of Sand Coulee in the Interstate fill where fill height is no higher than required for underpass clearance. Having attained the plateau level, I-94 will traverse grazing land and dry crop land to reach H3. The 90" structural plate drainage culvert at Mill Creek would appear to have a significant value as a stockpass in mitigating damages due to severance of the adjoining tract of land. At Station 278 a vehicular underpass appears to be warranted. The slightly curved alignment on the easterly portion of H2-H3 is warranted to place the Station 278 underpass in the head of a coulee for natural clearance under the Interstate as well as to cross Mill Creek at the most advantageous location from an earthwork standpoint.

Before proceeding easterly from H3 it appears desirable to mention one alternate to the Hill Route discussed herein. As has been stated, 70 MPH two lane Interstate Highway design does create problems where elevation must be gained to go from Valley to Hill alignment. Long deep cut sections result until elevation is gradually attained to bring the highway out of the ground. To alleviate the situation as shown on the profile between Station 181 and 240 an alignment was considered to follow a more curved alignment along the northern edge of the plateau from Sand Coulee easterly to approximately H3. This alignment was located close enough to the edge of the plateau so that most cut sections on the north side of the Interstate could have been daylighted and thus substantially improving the scenic value of the highway. Because of its length and relatively greater earthwork cost, this alignment would have added in excess of $100,000 to the construction cost as compared to the H2-H3 alignment shown herein. Obviously, because of the increased length, the plateau edge alignment would have had a greater annual cost and, reluctantly, it had to be dropped.

H3-H4

This segment of the Hill Route, covered by Figures 22 through 26, is common also to the Mill Creek Connection as well as being a continuation of the previously discussed H2-H3 segment. It traverses dry crop land and grazing land as it proceeds easterly to approximately Station 403 where it crosses the Huntley Irrigation Canal and thus again enters irrigated land. This alignment to return the Hill Route back to the P.T.W. at H4 is a part of the result of study of several alternates for an Interstate alignment south of the "Dead Water" which begins at Station 423. The reason for abandonment of alignments south of the dead water in favor of the northerly alignment shown to H4 and easterly toward H5 are discussed below. On the H3 to H4 alternate a Type II underpass is proposed at Kaiser Creek, Station 353, to allow passage under the Interstate for the relatively important Kaiser Creek road. East and west of Kaiser Creek, two structural plate vehicular underpasses appear to be warranted at Station 314 and 387 to mitigate severance damages for several property owners on a joint use basis.

H4=V4 to H5=V5

At the beginning of this segment, Hill and Valley Routes become common and remain so all of the way through the Interstate Rest Area to H5=V5. Reference should be made to Figures 26 through 33 for Plan-Profile Sheets in this area. As was briefly stated above, this segment's alignment was chosen over other possibilities after extensive study of several other alternates through this area. First tried was an alignment running through the hills approximately 1100 feet south of the "Dead Water", that lagoon-like feature created when the Northern Pacific Railway Company located their track, as now constructed, to cut off a bend in the Yellowstone River. This alignment, although laid out to take best advantage of the terrain, ran up such excessive earthwork quantities that it had to be dropped in favor of an alignment skirting the southerly edge of the Dead Water. Originally the Northern Pacific followed this alignment and when the railroad right-of-way was abandoned, the original alignment of U.S. Highway No. 10 occupied this alignment for more than twenty years until it too was moved to cut across the Dead Water's northerly edge. To get around the Dead Water a transcontinental telephone line, rural telephone line, a power line and the 8" Cenex fuel products line followed this alignment. In considering this alignment for I-94, a location was selected which would have placed the initial two lanes of a four lane Interstate facility on a fill section out in the Dead Water leaving the old roadway for the future two lanes of Interstate. Thus extensive cutting into the hillside would have been avoided where backslopes would have had to rise 200 feet above roadway level to daylight on a stable slope. This alignment appeared to have a lot of desirable features, notably a scenic route where independent grades could have been nicely worked into a four lane Interstate Highway. It too had to be dropped from consideration because of its relatively high construction cost; mainly due to more earthwork than will be required for the H4-H5 route shown herein and higher utility relocation costs. This alternate, while almost equal in length to the alignment proposed in this study, had approximately $114,000 higher initial cost.

On alignments running north of the Dead Water, numerous variations of the proposed route were tried until the final decision was made. Most notable of these alignments was one that would have been constructed over the P.T.W. While this would have saved approximately $150,000 worth of earthwork it did create serious problems in how to carry local traffic through the hills east of the Dead Water. Interchanges to allow this low volume local traffic access to the Interstate on either side of this area was considered but this concept fell far short of economic justification. No other solution of this local traffic situation could be found which, combined with I-94 built over the P.T.W., would allow as economical an initial cost for all Interstate and related facilities through the hills east of the Dead Water as the H4-H5 alignment shown. This routing has been established to take substantial earthwork advantage of the existing highway cut through these hills immediately east of the Dead Water by locating I-94 close enough to the P.T.W. to daylight the new into the old cut section and still preserve the existing highway. It has been located relative to the numerous utilities as to involve less renovation costs for these facilities than any other alternate considered.

Thus, having traversed the hills east of the Dead Water, the proposed common alignment arrives again in an irrigated valley at Station 558. Because very rough terrain rises abruptly from the edge of the irrigated valley in this vicinity it is not practical to consider a route other than one parallel to the P.T.W. east as far as H5. A hill alignment to avoid this irrigated land involved in excess of $200,000 in earthwork costs over the H4-H5 route proposed herein. Rather early in this study it was concluded that the Interstate must follow, in general, the P.T.W. at least as far east as H5 and a search was instituted to find the most satisfactory and economical location in that area extending laterally from the irrigation canal to the Northern Pacific tracks. For I-94 location it narrowed down to a consideration of routes parallel to and both north and south of the P.T.W. as well as building over the P.T.W. By taking advantage of the cut section of the existing highway these three alignments proved to be the least expensive on earthwork of all routes which could conceivably be laid through the sandstone ridge between Stations 686 and 699. Again building over the P.T.W. would cost some $17,000 less on earthwork than the route herein proposed, but to do so would present problems in handling local traffic, the solution of which would cost substantially in excess of this figure. If the existing U.S. Highway No. 10 were taken out of service as a through road for local traffic the most practical alternate route for this traffic appeared to be via old U.S. No. 10, which can be detected on Figure 65, as it follows the Northern Pacific tracks very closely in this vicinity. This old highway alignment would be quite satisfactory for a north frontage road,with I-94 built over or north of present U.S. No. 10, up to the point straight north of Station 690 as shown on Figure 65 Here a shear sandstone cliff rises within fifty feet of the railroad tracks to an elevation some 75 feet above the railroad tracks. This clay seamed sandstone cliff has caused rockfall which has completely covered the old highway and continually threatens the railroad. It is easy to see why the highway was moved out of this area. Building a frontage road through on this alignment, with excavation to establish a stable backslope, would be far more expensive than any saving in construction of I-94 anywhere but south of and parallel to the PTW as proposed herein. Again by locating I-94 close to the PTW through the hill it will be possible to daylight the new cut into the old and thus keep earthwork costs down while still maintaining the PTW for local traffice use.

The recommended location of the rest area occurs in this segment. The facility is discussed in more detail under the subsequent section of this report entitled, "Miscellaneous Considerations".

In the V4=H4 to V5=H5 segment, two structural plate underpasses have been proposed; at Station 526 just west of Spring Creek and at Station 662 just west of Automatic Creek. The former would provide access to the Federal Aviation Beacon and for local ranching operations. The south frontage road provides access to a road up Reed Creek. These underpasses have been located with a view to minimizing their cost by fitting them into the Interstate grade where a fill is required because of reasons other than providing clearance for an underpass. Cutting off the existing road up Automatic Creek with I-94 construction causes severance to several property owners which have been alleviated by an underpass at Station 662 and the short section of frontage road extending easterly from this structure.

H5 to H6

This segment, as shown on Figures 33 through 38, has been laid out to avoid irrigated land as much as possible and still not get any farther back than necessary into the comparatively rough terrain which crowds in on the irrigated valley in this area. Between Stations 738 and 765 the alignment does traverse irrigated land to minimize earthwork costs and to make the H5-H6 alignment as competitive as possible when compared with the alternate Valley routings. Cutting off this relatively small segment of irrigated land saves approximately $70,000 in initial costs, including an allowance for right-of-way and damages, compared to a slightly longer route farther south which would avoid all irrigated land. Where the alignment cuts off the piece of irrigated land it is proposed that the Waco-Custer Irrigation Canal be realigned to stay north of the Interstate and thus avoid two irrigation culverts through the highway. This would also avoid any maintenance of a section of irrigation canal that would otherwise be south of I-94 and thus not be readily accessible.

Other than the irrigated land described above, this segment traverses grazing land. This terrain, relatively speaking, is rougher and more irregular than any other area considered for Interstate construction in this study. East of Station 770, sandstone ledges are prominently in evidence. This is one area where, if selected for Interstate construction, final design may involve the raising of some grades shown herein to avoid rock excavation. That is, with soil profile data available, an economic analysis of grades and earthwork costs may dictate raising grades and borrowing fill material as the most economical method of accomplishing the earthwork involved.

Within this segment three grade separation structures are proposed. At Station 710 a stock underpass is proposed to match the existing stock pass under the PTW. At Station 768 a vehicular underpass should be provided for the local road that is being crossed. This is an important road in the operations of a large local ranch. The 84" drainage culvert at Station 861 should provide a stock pass and thus a part of this structure cost can be assigned to restoration of severance damages.

H6 to H7 and H7 to H8=V8

Reference should be made to Figures 38 through 44 for Plan-Profile Sheets covering these segments of the Hill Route. As one proceeds easterly from H6 through grazing land the rough and rocky nature of the terrain gradually moderates and presents the appearance of more ideal terrain for highway earthwork operations as compared to H5-H6. Two vehicular structural plate underpasses at Station 930 and 975 are proposed for the alignment of I-94 in these two segments both being justified on the basis of severance damages they will restore. From the underpass at Station 975 a south frontage road is justified to provide access to several sections of grazing land that otherwise would be isolated by Interstate construction.

The H7-H8 segment has been laid out to stay south and on the dry land side of the Waco-Custer Irrigation Canal. The terrain in this area is relatively smooth for a narrow band south of the canal before getting into much rougher ground farther south. Thus it was logical to keep the Interstate alignment as close to the canal as possible, consistent with tangent length and curve requirements required by the design standards. Unfortunately a 50 KV power transmission line has recently been built on this general alignment beginning at Station 1054 and, roughly paralleling the canal, running in a northeasterly direction. Some relocation of this transmission line and moving the highway slightly farther south than would otherwise be desirable will be necessary to accomodate both I-94 and the transmission line in this area.

H8=V8, the end of this study's Hill Route, is at the point of tangency of a circular curve which transitions from the Hill Route's last tangent to a tangent coinciding with I-94 alignment already established by Others. The location of the point of intersection of these two tangents is fixed by location of the back tangent to fit in the narrow band of relatively smooth terrain between the canal and the rougher terrain to the south. The last PIVC was determined by intersecting the grade by Others for I-94 east of this study area.

V1 - V2

Refer to the previous Hill Route discussion for this common Hill-Valley alignment on page 38.

V2 to V3

This segment is common to the Valley Route and the Hill Route via the Mill Creek Connection. Reference should be made to Figures 49 through 51 for the Plan-Profile Sheets covering this segment. This segment continues I-94 alignment parallel to the PTW through irrigated land and thus arrives at V3, the junction of the Valley Route continuing easterly along the PTW and the Mill Creek Connection to the Hill Route. The south frontage road would continue easterly and parallel to I-94 from V2, stopping for the Mill Creek Connection alignment at Station 208 but continuing easterly all the way to Station 419 for the Valley Route.

V3 to V4

This segment, as shown on Plan-Profile Sheets, Figures 51 through 58, continues the Valley Route parallel to the PTW. The south frontage road also continues through most of this segment from V3 to Station 419 where it terminates just west of the Dead Water.

Between Station 251 and 258 a steep ridge fingers out toward the PTW and will show as a sharp irregularity in the groundline for the future pair of Interstate lanes although it ends prior to greatly influencing the ground line for the proposed initial westbound pair of I-94 lanes. In this area relocation of the Huntley Irrigation Canal is required. It is proposed that this canal be channel changed via a culverted section under the south frontage road and the initial and future pair of I-94 lanes, through an earthen fill section parallel to and between the PTW and I-94, and then back through a culverted section under the I-94 lanes and south frontage road to its present alignment.

At Station 280 a Type II underpass is proposed. This structure will allow local traffic generated by the south frontage road to cross the

Interstate for access to the PTW and vice versa. Between V3 and V4, nine irrigated farming units are severed by this Interstate alignment and thus substantial severance damages are involved. This structure will mitigate a substantial amount of this severance damage. It's location has been selected to be as near as possible to what is judged to be the best location for the local traffic pattern after I-94 construction and still take some advantage of the fill required by crossing the ridge discussed above. Testimony given at the public hearing indicates that locating the Interstate Highway along this alignment would have a substantial adverse effect on the sugar beet economy of this irrigated valley. The irrigated land which would be taken out of production by Interstate R/W requirements could reflect changes in established routines of marketing sugar beets and might force changes in crop types. The economic ramifications for the Valley Route appear to be extensive. The location of all of the various underpass structures on the Valley Route cannot intelligently be located to take into consideration local traffic needs until the decision is made and approved as to which route will be selected for I-94. If the Valley Route is chosen its effect on the agricultural pattern of the area should be assessed on final design. In this case some shifting of location of the underpass at Station 280 may be warranted.

In the vicinity of Stations 320 to 350 a very restrictive situation exists for desirable Interstate alignment caused by the present location of the Bull Mountain beet dump on the left and a farm unit on the right. The PTW has reverse curves through this area.

Beyond Station 350 I-94 and frontage road construction would be routine for the remainder of this segment to its easterly end at V4=H4, a common point with the Hill Route as previously discussed.

V4=H4 to V5=H5

This segment of the Valley Route as shown on the Plan-Profile Sheets, Figures 58 through 65, is almost identical in alignment with this same segment on the Hill Route as previously discussed on page 41 although the grade is slightly different on the easterly end of this segment. Reference should be made to the afore mentioned Hill Route discussion which is equally applicable to the Valley Route.

V5 to V6

Plan-Profile Sheets on Figures 65 through 68 show this segment in detail. This segment begins the traverse of the second irrigated valley section of the Waco-Custer Irrigation District with the crossing of this canal at Station 737. The proposed I-94 alignment would be parallel to and on the south side of the PTW. It would require a south frontage road beginning at Station 737 which would continue all of the way through this segment for all alternates but the Thurmond Coulee Connection (V6-H6). For this alternate the frontage road would stop at Station 800.

Selection of the proposed alignment for the Interstate in this segment on the south side of the PTW is really a part of considerations discussed previously on page 44 for the H4-H5 segment of the Hill Route. As was there stated the choice resolved itself down to consideration of routings immediately north, south and over the PTW for I-94. The handling of local traffic as the most important factor in the selection of the proposed route. The alignment of old U.S. Highway No. 10, which leaves the P.T.W. at Station 794 and proceeds westerly parallel to the Northern Pacific tracks, invites consideration for either Interstate or frontage road location but the transcontinental telephone line and 8" Cenex fuel products line along either side of this old highway would involve prohibitively expensive conflicts in any such consideration.

On the Valley Route at Station 775 a Type II underpass is proposed to serve as local access and for access to and from the P.T.W. This structure and the Type II underpass proposed at Station 881 of the Valley Route are warranted to mitigate substantial severance damages caused by an Interstate highway through this irrigated valley and to restore local access for the eight farm units likely to use these facilities. Both of these underpasses have been located to minimize earthwork requirements on Interstate approach fills to the structure. By thus minimizing the approach fill requirements these two structures have a lower cost than one structure complete, located at say Station 800. For one structure only at Station 800 a substantial approach fill would be required for 70 M.P.H. and two lane Interstate design which all would have to be built up solely for approach purposes.

V6 to V7

This segment of the Valley Route continues I-94 parallel to the P.T.W. through irrigated land as discussed for the previous two segments. It is covered on the Plan-Profile Sheets, Figures 68 and 69, and would require a south frontage road continuous through this segment. The easterly terminus of this segment at V7 is the point where the Sand Creek Connection would leave the P.T.W. alignment as an alternate to the Valley Route.

V7 to V8

Reference should be made to Figures 69 through 76 for Plan-Profile Sheets covering this segment. This I-94 alignment possibility would parallel the P.T.W. through irrigated land all of the way to Station 1045. Here the proposed alignment would leave the P.T.W. and proceed across irrigated meadows to a crossing of the Waco-Custer Irrigation Canal at Station 1095 and thence into hilly grazing land to V8=H8, the end of this study. At this point of junction with the Hill Route and approved Interstate alignment by Others the Valley Route grade would intersect the grade proposed for I-94 by Others at Station 1114. A 5800 foot vertical curve would transition between these two grades.

In this segment the afore mentioned Type II underpass at Station 881 and a Type II underpass at Station 986 are proposed. The latter serves to mitigate severance damages for the adjacent properties severed by this Interstate alignment proposal and has an important access function for maintenance of a flume in the Waco-Custer Irrigation Canal at the mouth of Sand Creek opposite Station 1005. This structure would also allow the local road up Sand Creek to connect with the P.T.W. It has been located as shown to minimize earthwork requirements.

A south frontage road is proposed to continue easterly from V7 to the underpass at Station 881 and connection with the P.T.W. At Station 936 it is proposed that a south frontage road be provided to extend easterly to Station 1071 with access to the P.T.W. at the Station 986 underpass.

Between Stations 885 and 909 a renovation of the Waco-Custer Irrigation Canal would be required. This renovation would be very similar to that proposed for the Huntley Irrigation Canal as previously discussed on page 49 with culverts under both the initial and future I-94 lanes and a canal realignment between these two culverted sections, parallel to the P.T.W. between the present highway and the Interstate. Extensive relocation of the transcontinental telephone lines is also involved.

Between Station 1010 and 1024, Sand Creek will have to be channel changed.

Mill Creek Connection - V3 to H3

This connection, as shown on Figures 77 through 80, offers an alternate way to transition from the Valley or P.T.W. alignment to the Hill Route. Like the Sand Coulee alignment between V2 and H3 this route eases the approach problem in gaining the elevation of the plateau by taking advantage of the natural slope along the east side of Mill Creek. It has the most economical earthwork situation of the two west end hill alternates but this advantage is largely offset by a greater length than via Sand Coulee. This alignment would leave irrigated land with the canal crossing at Station 228 and would thence traverse grazing and dry crop land. Mill Creek too has the undesirable feature of remaining in a deep cut section as the highway gains the elevation of the plateau. In this respect it is more objectionable than the Sand Coulee approach to the plateau.

Two structural plate vehicular underpasses are proposed in V3-H3 segment. At Station 240, the structure and location proposed would also serve for Mill Creek drainage which justified this otherwise marginal grade separation facility. At Station 281, an important local road should be allowed to underpass I-94.

Grade and alignment of the V3-H3 line becomes common with the Hill Route at H3.

Thurmond Coulee Connection - V6 to H6

This connection, whose Plan-Profile data is shown on Figures 81 through 84, offers an alternate way to transition to and from the Valley or P.T.W. alignment for the east end portion of the study and can be considered in lieu of Valley-Hill transitions as studied via H5 to H6 and V7 to H7. This connection, providing the shortest overall route of east end alternates, leaves the P.T.W. and traverses irrigated land to Station 841 and then grazing land to H6. The Thurmond Coulee grade offers less of an objectionable "trench section" characteristics of all other Valley-Hill transitions. Its grade continues east as far as Station 925+60 before becoming common with the Hill Route although the alignment of the V6-H6 connection becomes common with the Hill Route at Hill Route Station 868+76.

The previously discussed 84" drainage culvert at Station 861 should offer an additional benefit as a stock pass.

Sand Creek Connection - V7 to H7

This connection too offers an alternate way to transition from the P.T.W. alignment at V7 to the Hill Route at H7. Reference should be made to Figures 85 through 89 for this connection's Plan-Profile Sheets. It is the least expensive, earthwork wise, of all east end alternates but is the longest Valley to Hill alignment. The grades from valley elevation to plateau have the characteristic undesirable "trench section" quality. The Sand Creek connection traverses irrigated land to Station 877 and thence grazing land to H7.

Underpasses are proposed at Station 875, Station 934 and Station 981. The former fills the same function as that discussed for Station 881 on the Valley Route. The latter is the counterpart of that structural plate vehicular underpass at Hill Route, Station 975.

South frontage road is proposed from V7 to the Station 875 underpass and thence northerly to the P.T.W.

The Sand Creek connection becomes common in line with the Hill Route at Station 986 but requires additional length to gain common grade with the Hill Route at Station 998.

RIGHT-OF-WAY AND LOCAL ACCESS

General

Probably on few other rural Interstate projects has right-of-way and severance damages been a bigger factor in the study of Interstate location. There are approximately twenty-five farm units that would be severed by an Interstate alignment parallel to the PTW. Most of this land thus traversed is $350.00 per acre irrigated farm land. Right-of-way and severance damage estimates for use in the economic analysis section of this study indicate that the obvious construction cost advantage of an Interstate Route parallel to the PTW, as compared to a Hill Route largely avoiding irrigated land, is more than wiped out by comparatively higher right-of-way and related costs for the Valley Route on the west end of the studied area and is also largely offset on the east end of the study. The route alternates shown for consideration via the three connections at Mill Creek, Thurmond Coulee and Sand Creek offer somewhat of a compromise between the relatively high cost of right-of-way in the valley and of relatively high cost of highway construction in the hills. It is the intent of this section of the report to discuss, in general, the results of the very comprehensive right-of-way analysis prepared by the Montana State Highway Commission.

The following route by route summary of the estimated acreage required for right-of-way of various types of land gives a general picture of each route's relationship to the agricultural pattern of this study area. The various segments have been combined into the three route alternates for the west end of the study and the four route alternates considered for the east end. Division between east and west ends has been made at V5-H5.

SUMMARY OF R/W ACREAGES BY LAND TYPES

ROUTE ALTERNATE	ESTIMATED ACRES R/W *Irrigated	Dry Crop	Grazing
WEST END			
V1-V2-V3-V4-V5 (Valley Route)	411.7	0.0	121.2
V1-H2-H3-H4-H5 (Hill Route)	204.0	59.9	246.2
V1-V2-V3-H3-H4-H5 (Mill Creek Connection)	252.5	36.5	224.9
EAST END			
V5-V6-V7-V8 (Valley Route)	274.2	0.0	43.5
V5-V6-V7-H7-H8 (Sand Creek Connection)	123.6	0.0	189.9
V5-V6-H6-H7-H8 (Thurmond Coulee)	90.0	0.0	206.8
H5-H6-H7-H8 (Hill Route)	18.6	3.0	266.6

*Capable of being irrigated, i.e. under irrigation ditch, regardless of present use.

Right-of-way and related cost estimates were requested and furnished for these costs with the local access facilities proposed herein and for a hypothetical situation wherein severance damages were estimated for the various Interstate alternates without any local access facilities. The former figures are those used in the cost estimate section of this report. The difference between the estimates with and without access served as a guide to justification forlocal access construction costs. The following tabulation segment by segment, shows the relationship between construction cost of access facilities and the difference in right-of-way and severance damages with and without local access. The latter cost differences are listed under heading "Damages Restored." Construction costs of underpasses and frontage roads are listed under heading "Local Access Cost." Earthwork costs associated with underpass approaches, when greater than required if that structure were not installed, were estimated as to the additional amount required for the underpass and that figure too was included under "Local Access Cost."

Fencing and drainage, associated with frontage road construction, have been included in "Local Access Costs."

Several of the local roads restored to continuity by underpasses have an economic value greater than the severance damages to I-94 abutting property if that road were closed. This impact factor is difficult and involved to evaluate. It has not been determined for use under "Damages Restored" except in the case of the Sand Coulee road. Here a value has been included for damages to other than abutting property if that road were closed. Certainly the underpass at Pompeys Pillar has a far greater value to non-abutting property than to those tracts abutting the proposed Interstate alignment. To a somewhat less degree this is true also with all Type II underpasses and especially at the Kaiser, Witham and Sand Creek roads. Thus actual "Damage Restored" values would be higher than shown.

The following segment by segment comparison, as shown on Plate 3, is rather arbitrary in comparing damages restored to local access costs. For example, $36,000 of the Local Access Cost under H3-H4 is for the Kaiser Creek underpass which has a substantial benefit to the local ranch. . The Severance Damages show up under H4-H5. Likewise, V7-H7 could well be grouped with H7-H8 for comparison because the local access facilities and severance damages of these two segments are very interdependent. Also consideration of H6-H7-H8 and V5-V6-V7-V8 as separate segments, for the purposes of this comparison, is hardly valid. For a more valid comparison, Plate 3 also shows a summary of these costs for each overall route possibility. The division in route summary into "West Portion" and "East Portion" has been made at V5=H5.

The excess of cost on the west end for Local Access facilities as compared to Damage Restored is due to the cost of the Type I underpass and the new County road bridge over Fly Creek at the Town of Pompeys Pillar. Regard the excess of Local Access costs over Damage Restored values for say V1 through V3 as a $175,000 capital improvement figure that must be amortized by local traffic user costs. Figuring an amortization period of say 30 years at 6%, the approximate annual cost to be offset by local traffic benefits would be $12,715. On the basis of the 266 ADT current local traffic count likely to use this underpass and bridge a value of approximately $0.13 per day would have to be assigned to each vehicle using this underpass. The cost/benefit relationship seems reasonable and indicates that the local access facilities, at the Town of Pompeys Pillar, are economically justified.

In conclusion, it is believed that all local access facilities proposed in this study are economically justified for the reasons stated above and according to the figures tabulated on the following Plate 3.

As has been discussed in the previous section on "Geometrics and Location", page 44, wiping out of the existing highway by building the Interstate over the PTW and providing interchanges on either side of this area for local traffic access to a through highway is far from being economically feasible. In preliminary estimating of this section of Interstate prior to the Consultants becoming associated with this study the possibility of an interchange near Kaiser Creek was considered. As a part of this study this possibility was analyzed. The twenty-four odd mile distance between Pompeys Pillar Monument interchange, located about two miles west of the Town, and the interchange in the Town of Custer is relatively long without intermediate access to the Interstate. However, based on traffic counts on local roads entering the PTW in this interval and estimates of traffic likely to be generated by farm unit headquarters now abutting the PTW, an interchange between those planned at Pompeys Pillar and Custer cannot be shown to be economically feasible. This statement is made on the basis of the PTW remaining intact and thus available to convey local traffic to the interchanges on either end of the studied area. The traffic count indicates that most of the local traffic entering the PTW does so at the Town of Pompeys Pillar. This traffic would have rather direct access to the interchange two miles west of town via the underpass at the Town and the PTW. For the purposes of this evaluation of interchange justification, a figure of approximately $40.00 per year per vehicle and $45.00 per year per vehicle has been used for road user costs on two lane Interstate and the PTW. It has been assumed that the traffic volume likely to be involved on the PTW as the through road for this area will warrant its continued maintenance as a bituminous surfaced road.

Current ADT estimates on local roads entering the PTW are as follows. Stationing is Valley Route stationing. All roads listed enter from the south except at Station 662. Local roads not listed have a current ADT of less than 10.

STATION	1964 ADT	1988 ADT	LOCAL ACCESS FACILITY PROVIDED
59	240	450	Type I Underpass
75	64	120	South Frontage Road East & Existing Oiled Road Southwest to connect with Station 59 Underpass.
113	14	26	South Frontage Road
144	7	13	South Frontage Road
167	10	19	South Frontage Road - Valley Route Type II Underpass - Hill Route
280	9	17	Underpass
662	15	28	Underpass

Local traffic generated by farm unit headquarters which directly abut the PTW and which might use an interchange say in the vicinity of Kaiser Creek have been estimated on the basis of house count and assuming that each house may generate three one way trips per day. This count shows 8 dwelling units between the Sand Coulee Road and Kaiser Creek and 19 dwelling units between Kaiser Creek and a point 2½ miles west of Custer. It has been further estimated that 60% of the trips to and from these dwelling units, located east of Kaiser Creek, will be to and from the west and that swelling units west of Kaiser Creek will split 70%/30% with the majority wanting to travel west.

At the Public Hearing, the method of local access was thoroughly discussed and shown by the exhibit map. Access to interchanges, as the only entrance to the Interstate via the PTW as a local through road was carefully explained. At this Public Hearing, no objection was expressed to the lack of an interchange all of the way between the interchange at Pompeys Pillar and Custer. The Public Hearing covering the Interstate location for this project was held in Custer on June 15, 1966.

For the reasons discussed above, no interchange is proposed for inclusion in the Interstate facilities recommended herein.

Plate 3

COMPARISON OF SEVERANCE DAMAGES TO LOCAL ACCESS COSTS

SEGMENT	DAMAGE RESTORED	LOCAL ACCESS COST
WEST PORTION		
V1-V2	$ 64,545	$ 236,373
V2-V3	60,580	63,392
V3-V4	311,418	276,980
V2-H3	148,177	95,444
V3-H3	93,940	81,679
H3-H4	15,935	51,640
V4-H4 - V5-H5	225,760	114,298
SUMMARY		
V1-V2-V3-V4-V5 (P.T.W. Route)	662,303	691,043
V1-H2-H3-H4-H5 (Hill Route)	454,417	497,755
V1-V2-V3-H3-H4-H5 (Mill Creek Connection	460,760	547,382
EAST PORTION		
V5-V6	183,770	161,020
V6-V7	22,775	32,281
V7-V8	186,837	202,181
V6-H6	22,763	5,083
V7-H7	54,509	95,226
H5-H6	113,674	21,440
H6-H7	17,864	29,180
H7-H8	54,884	0
SUMMARY		
V5-V6-V7-V8 (P.T.W. Route)	393,382	395,482
H5-H6-H7-H8 (Hill Route)	186,422	50,620
V5-V6-H6-H7-H8 (Thurmond Coulee)	279,281	195,283
V5-V6-V7-H7-H8 (Sand Creek)	315,938	288,527

MAJOR UNDERPASS AND DRAINAGE STRUCTURES

Major structures, as proposed in this study, are bridge type underpasses for vehicular traffic and two bridges over Fly Creek adjacent to Pompeys Pillar. As discussed in the previous section on "Right-of Way and Local Access", no interchanges were found to be justified for the area covered by this study.

Major underpasses are herein defined as reinforced concrete structures carrying Interstate traffic over local roads.

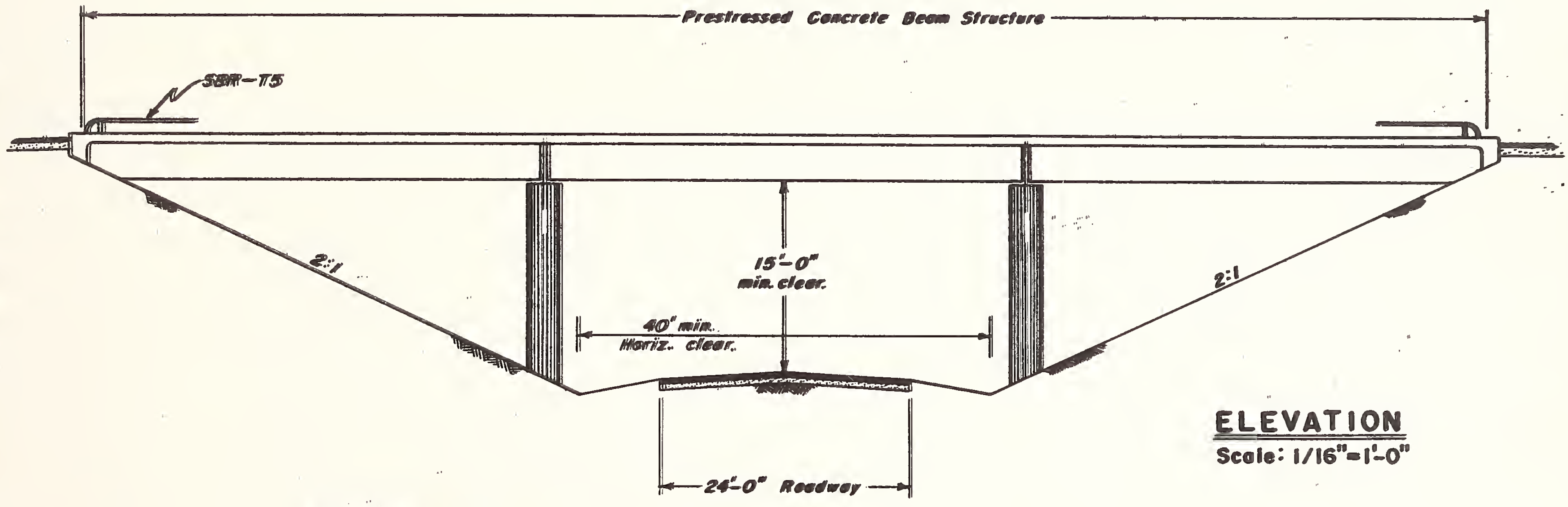
Under the Agreement for this engineering service the Consultant is responsible for specifying size and location for each bridge type structure in the detail required to establish general design features of the structure. Structure design will be accomplished by the Montana State Highway Commission. The structure details for Type I and II reinforced concrete vehicular underpasses as presented herein are intended to fulfill the Agreement requirements for the preliminary study phase of this engineering service.

For the one relatively high traffic local road directly out of Pompeys Pillar, a Type I structure is proposed. For the relatively low traffic local public roads throughout the rest of the study area Type II structures are proposed. Location of the Type II underpasses are discussed in the segment by segment discussion of local access facilities under the previous section entitled "Geometrics and Location." They are also shown on the "Location Map of Alternates Studied", Figures 1 thru 4 and on "Plan-Profile" sheets, Figures 13 thru 89. Type II structure costs, complete except for earthwork on I-94 approaches, have been estimated herein on the basis of a $36,000 cost per structure. The Type I underpass has been estimated on the basis of $10.50 per square foot over an area equal to the overall 136' length and 46' width of the structure or say $65,700 for this structure, exclusive of earthwork. The width allows one foot for railing cost. In passing, it should be pointed out that approach fills to carry I-94, as a two lane, 70 MPH highway, over the Type I underpass at Pompeys Pillar costs an approximate $97,600. A four lane facility with two structures and approach fills for 70 MPH stopping sight distance only would have an estimated $202,000 cost. Thus the eventually required four lane underpass facility at Pompey's Pillar would cost only an estimated $38,700 more than the two lane facility proposed herein if constructed with initial I-94 facilities. This estimate is based on a four lane structure 69 feet in width. To add for four lanes in the future would cost approximately $108,000. It is realized that the cost of two additional miles of four lane Interstate would have to be thrown into this consideration to extend four lane beyond the Town of Pompeys Pillar. It is suggested that the economics of this situation may be worth further consideration prior to final design.

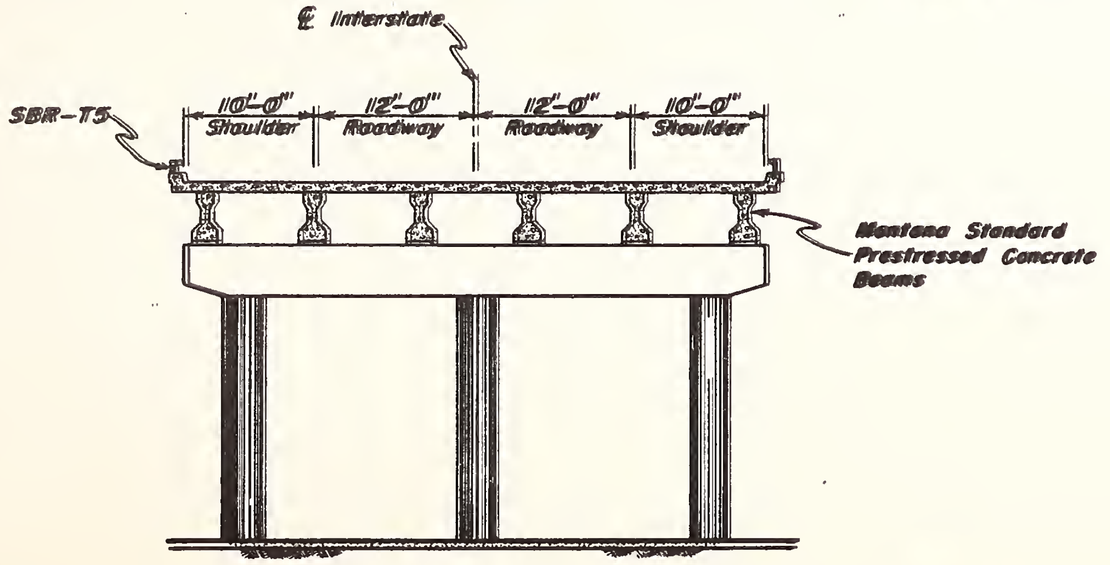
Vehicular and stock underpasses for private or semiprivate use, as contrasted with Type I and II underpasses for public roads, have been estimated on the basis of a circular structural plate cross-section conforming to Montana State Highway Commission standard drawing No. 66-04 and 66-05 where a drainage function is also incorporated.

The two Fly Creek bridges have been estimated on the basis of reinforced concrete structures , 125 feet in length and with 26 foot roadway width for the County road bridge and 44 foot roadway width for the Interstate Bridge. Cost has been based on $10.50 for area of the length indicated times overall structure widths of 32 feet and 46 feet. Again an extra foot of structure width has been allowed for railing. The lengths indicated above are overall deck lengths. As indicated in the previous section on "Hydraulics and Drainage" the clear waterway under these bridges should be studied further prior to final bridge design but nothing indicates that the required waterway clear span between mid-span supports will exceed limitations of standard prestressed concrete girders.

FIGURE 10



ELEVATION
Scale: 1/16"=1'-0"



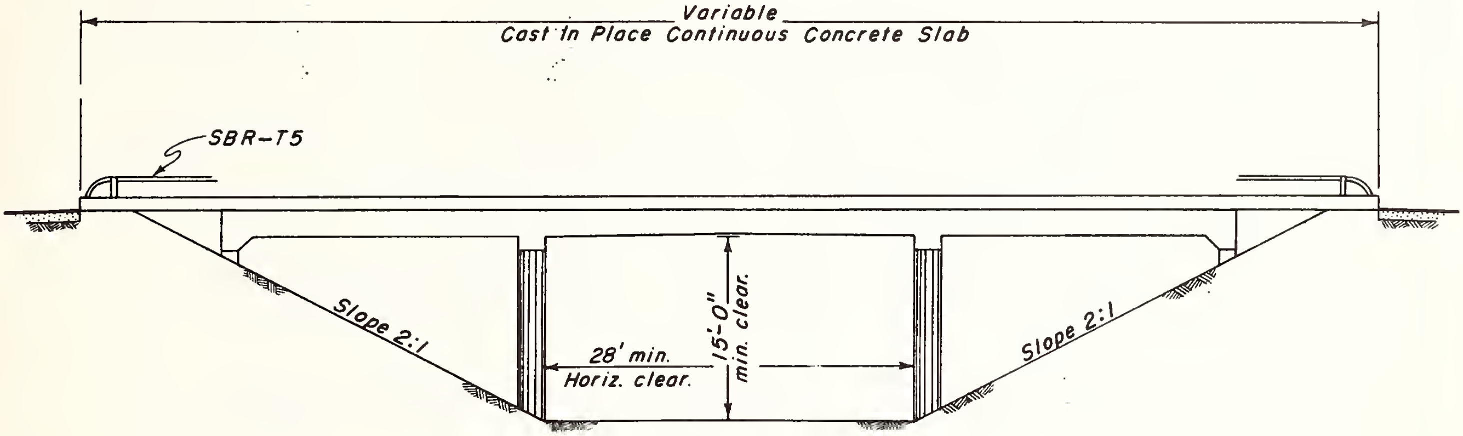
SECTION
Scale: 1/16"=1'-0"

NOTES

1. *Typical Prestress Structures:*
   This structure layout indicates typical construction proposed for the Pompeys Pillar separation.
2. *Design Loading:*
   HS20-44 or alternate military loading.

MAJOR VEHICULAR UNDERPASS
— TYPE I —

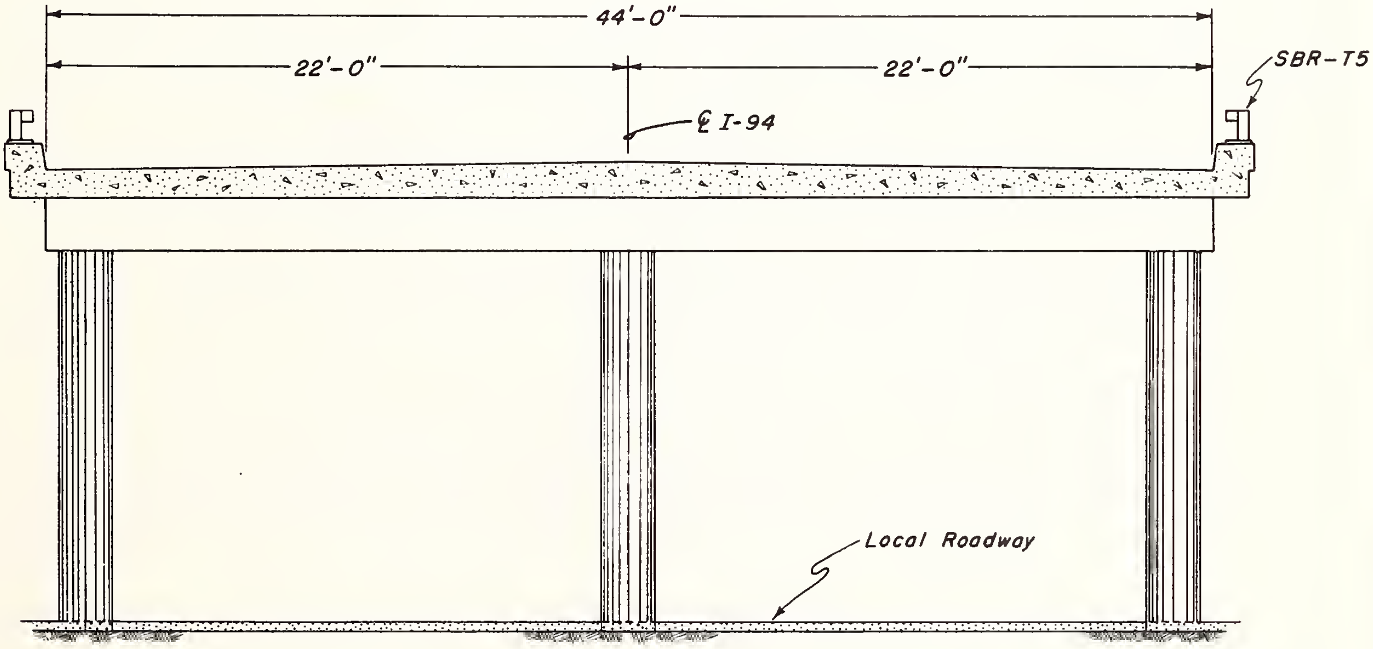
FIGURE 11



Typical Reinforced Concrete Structure
Proposed for several public road crossings.

ELEVATION
Scale: 1/16"=1'-0"

Design Loading
HS20-44 or alternate military loading.



SECTION
Scale: 1/8" = 1'-0"

MAJOR VEHICULAR UNDERPASS
— TYPE II —

MISCELLANEOUS CONSIDERATIONS

Utilities

Utilities encountered in this Study and requiring adjustment to conform them with Interstate Highway improvements proposed herein are:

Mountain States Telephone Company - Beach/Helena Toll Line

Yellowstone Valley Electric Cooperative - Power Distribution and Transmission Pole Lines.

Project Telephone Company - Rural Telephone Lines Either Underbuilt on Power Poles or as Separate Pole Lines

Independent Telephone Company of Custer, Montana - Rural Telephone Lines as Underbuilt on Power Lines

Cenex Pipe Line - 8" Fuel Products Line

The general location of these utilities, where adjustment is necessary, is described in the segment by segment discussion in "Geometrics and Location". Since these utilities generally follow the alignment of old U.S. Highway No. 10 the areas of greatest utility conflict are where the I-94 alternates cross or parallel the alignment of this old highway. Care has been exercised to minimize these utility conflicts, and thus the cost they involve, but there are times when such adjustments are necessary and desirable to allow use of I-94 alignment possibilities that effect a lowering of the overall construction cost of the highway.

Each utility conflict required an appraisal of the situation to determine just how the adjustment should be made to accomplish a satisfactory adjustment with the least cost. Obviously on final design for the I-94 alignment selected the utility conflicts involved will need to be reviewed with the utility sub-division of the M.S.H.C. right-of-way department to be sure the most satisfactory and economical solution of these conflicts is reached. For this preliminary study, having determined the way which appeared best to resolve the conflict, estimates of work to be done were made and unit prices of the various items of work were obtained from the Montana State Highway Commission. Thus the cost estimates for "Utilities" as shown on Plate 4, "Construction Cost Comparison of Alternates Studies" were prepared.

Rest Area

The scope of work spelled out in the Agreement for engineering services on this project provided that a rest area be studied and recommended for location within this studied area. In general the location specified was near Mill Creek although several miles latitude was judged to be allowed in selecting what appears to the Consultant to be the best site.

Several potential sites were selected for study and all sites thus selected were rated according to the following list of qualities which were judged to be important or desirable:

(1) Trees
(2) Shelter from prevailing wind
(3) View
(4) Prospects for ground water supply
(5) Prospects for satisfactory septic tank drain field
(6) Chemical quality of ground water
(7) Topography of site relative to water supply and disposal of sewage
(8) Expansion possibilities
(9) Ramp roads - how they fit in grade with I-94

It was found that no site rated excellent on all of these counts. Indeed several sites considered would have provided a more scenic view than the site recommended but on the balance the site proposed herein rated higher than any other site considered. This site is located at approximate Station 606 which places it in a position common to all alternates. Reference should be made to Figures 30 and 62 for a pictorial layout of the recommended site. The site is now covered with large cottonwood trees. While many of these trees probably should be removed because they are both unsightly and in danger of losing major limbs in a severe wind storm they do demonstrate that the ground on this site should do a satisfactory job of growing trees and shrubs.

This site is located on the south side of the PTW. A water sample was taken at a nearby ranch well as the best evidence of the water supply which may be obtained for this site. The well is 80 feet deep. This water sample was submitted to the Montana State Board of Health for laboratory analysis and recommendations as to its acceptability for drinking water. Their report states in part --

> "The total mineral content of this water as determined by the total dissolved solids is 1010 milligrams per liter, a content which is moderately low and classifies the water as fair (between 500 and 1200 milligrams per liter) from the standpoint of drinking. Waters in this class are described as having no distinct taste as a rule. They can usually be recommended for drinking.
>
> This water has a total hardness, calculated as calcium carbonate, of 22 milligrams per liter of approximately 1 grain per gallon. Such hardness classifies the water as relatively soft (between 0 and 5 grains per gallon). This water contains 0.00 milligrams per liter of iron."

On the bais of this report it would appear that there is a fair prospect for obtaining an acceptable water supply at the proposed rest area location.

Drain fields for septic tanks are said to perform satisfactorily in this vicinity. If this location is selected for the rest area, prior to final design the site should be tested for adequacy as to drain fields with percolation tests.

Other sites that have been studied but are less desirable are:

(1) At Kaiser Creek on the Hill Route. This site would appear most adaptable to development of a rest area using a configuration with a combined exit and entrance similar to Figure 18, Page 39 of A.A.S.H.O publication entitled "A Policy on Safety Rest Areas for the National System of Interstate and Defense Highways". It would appear that from a space standpoint a rest area for west bound traffic could be located opposite Station 365 with an area for east bound traffic opposite Station 353. These sites would appear to have most of the desirable features of the recommended site except that separate water supply and sewage facilities would be required. The big disadvantage of these sites would be their relative elevation compared to the grade of I-94. They are from 20 to 30 feet below the finished grade proposed for I-94.

(2) Plateau Site Between Kaiser Creek and Mill Creek. This Hill Route site would also be applicable to a routing via the Mill Creek Connection. Opposite Station 280, as shown on Figure 21, west bound traffic could swing off onto a salient feature in the plateau edge which should afford a view looking out over the Yellowstone Valley. This site would be a common exit/entrance layout similar to (1) above. A similar facility on the south side of I-94 opposite say Station 270 could be readily worked

in from a space standpoint but this site would not have a view like that afforded on the north side of I-94. The only safe way to gain a north of highway site for east bound traffic at this location would be via an underpass. The location for the local access underpass planned for Station 278 on the Hill Route could be utilized for this purpose but the structural plate underpass, as proposed for local traffic, would not be satisfactory from an alignment, width and grade standpoint for rest area traffic. Such an arrangement whereby both local and I-94 traffic would use the same underpass would breach the controlled access feature of the Interstate. Thus the required facility to get east bound traffic into a rest area on the north side of I-94 would require most of the underpass and ramp facilities of a full fledged interchange. This would cost an estimated $105,000 over the cost of the local traffic underpass planned for this location. There are no existing trees of any significance on this site. Water supply prospects on this site, as on all sites discussed below, cannot be evaluated without investigation beyond that warranted for this study.

(3) Mouth of Mill Creek on Valley or Mill Creek Connection Routing. By shifting I-94 alignment from that shown on Figures 51/52 and 77/78 a valley level rest area could be laid out in the mouth of Mill Creek and/or just west of Mill Creek but the size of these sites would be very confining and would have undesirable geometric qualities relative to I-94 alignment and grade. Two sets of farm buildings would very likely have to be taken for right-of-way.

(4) Plateau Level Site East of Sand Coulee - Hill Route. By shifting I-94 alignment from that shown on Figures 18/19 to a location parallel and say 900 feet northerly from the planned alignment it appears possible

to locate a rest area for west bound traffic opposite Station 200 on the north side of I-94 and a rest area for east bound traffic opposite Station 187 on the south side of I-94. These two sites should afford a good view of the valley. This alternate, while taking care of the view for the rest area, would have serious consequences as far as I-94 is concerned. Such a shifting of alignment would take out the farm headquarter buildings between Stations 165-175 and/or chew up irrigated meadows more extensively than the proposed alignment for the Hill Route.

(5) Hill Site at Station 510. This grazing land site between Station 505 and 520 is common to all alternates. This site's biggest disadvantage is that is is traversed by the Cenex Fuel Products Pipeline which would have to be extensively relocated to use this site for a rest area. This site has no existing tree cover or other shelter and would have the probability of deep drilling for a water supply if acceptable water can be obtained by drilling.

(6) Dead Water Site. This site, common to all alternates, would involve fitting a rest area into that piece of land between the Dead Water and the PTW between Stations 425 and 450. The size of this site would be very confining for rest area development and would require extensive filling to bring the level of the site above flood level of the Yellowstone River which is hydraulically connected to the Dead Water lagoon.

It is recommended that the site proposed in this report, between Station 588 and 617, be planned for the Interstate Rest Area.

Division Into Construction Contracts

In the Agreement for engineering services on this project it is stated that this study area will be broken into two sections for final design and construction contract award. In making earthwork determinations for this study the Consultant has envisioned that a point on either side of the proposed rest area, where the proposed I-94 alignment is in close proximity to the PTW, would make an acceptable location for this division into two construction contracts. With the grades laid as proposed in this report a balance point on earthwork occurs at Station 606. By adjusting grades somewhat this balance point could be shifted either east or west to make the earthwork situation fit with the division into construction contracts.

Access to Highway Maintenance Facilities

The Agreement for this engineering service requires that the Consultant make recommendations as to access to highway maintenance facilities. The situation, upon completion of I-94 as herein proposed, has been discussed with the Division Maintenance Engineer and the District Engineer in the Billings office of the Montana State Highway Commission. Since all alternates for I-94 proposed herein will be southerly of the PTW and will leave this present highway intact as a through road, no problems are envisioned in maintenance of I-94 with access through the interchanges at Pompeys Pillar Monument and in the Town of Custer. Thus no facilities relative to I-94 maintenance are proposed in this study.

Road User Cost Determination

A study of the "Geometric Summary", Plate 2, as bound with the previous section of this report entitled, "Geometrics and Location", indicates that none of the routes presented in this study have a significant "Road User" advantage over the other route alternates with which they compete for position as the recommended route. As one would expect on the West End, the Valley Route has a lesser average grade because it does not have to climb over any hills to speak of and it likewise has a lesser percentage of its total length in circular curves.

The maximum grades listed for each alternate do not give an altogether true picture because, with long crest vertical curves beginning almost back to back with sag vertical curves, the actual average grade of any alternate would be less than shown. The average grades shown are from PIVC to PIVC. Thus, taking for example the most severe condition possible under the design criteria established for this study, a 3% ascending grade and a 3% descending with a 9,600 foot vertical curve, the actual average grade, from point of curve to point of tangency, is not 1.5% but rather 0.75% when figured from beginning of curve to top of crest as the difference of elevation. This factor would make the average grade situation closer even than that listed on the Geometric Summary if it were practical to figure average grades to this finite degree. Even in figuring average grades in the conventional manner shown on the Geometric Summary, the longitudinal grades on any route alternate are not steep enough to measurably affect User Costs. In figuring User Costs every alternate falls into the 0-3% gradient classification and circular curves do not increase User Costs values as determined for tangent sections of highway.

In figuring User Costs the year 1980 has been taken as it is the mid-year between the highway construction and the design year of 1990.

Following are the 1980 ADT and DHV calculated for figuring User Costs.

	ADT	DHV	*ADJUSTED ADT
West End of Study (V1=H1 to V4=H4)	3795	493	5152
Common Line-All Alternates (V4=H4 to V5=H5)	3728	485	5061
East End of Study (V5-H5 to V8=H8)	3728	485	5061

*Equivalent number of passenger cars to ADT with 14.3% commercial vehicles and figuring one commercial vehicle equals 3.5 passenger cars. This is the value of "A" used in the Road User Cost formula discussed below.

The type of operation for determining User Costs has been taken as "Free" inasmuch as the above listed values for DHV, when divided by the 790 VPH (design or practical capacity of this highway), gives values of approximately 0.62 and 0.61. When this relationship of DHV to practical capacity is less than 0.75, the type of operation is considered to be "Free". To determine running speed in MPH the tables on page 85 and 89 of "Road User Benefit Analysis for Highway Improvements" were used to arrive at a value of 46 MPH. Having determined the various elements required to enter Table 7 on page 132 of "Road Users Benefit Analysis for

Highway Improvements" a value of $0.0894 was arrived at for User Cost per vehicle mile. For use in this economic analysis this value was adjusted upward to $0.0949 in recognition of the current price of gasoline in Montana at 40¢ per gallon compared to the 32¢/gallon used in the Text. Then Road User Costs were determined for each route alternate on the basis of the formula: A x U x L x 365

Where "A" is the Adjusted ADT as listed above.

Where "L" is the route alternate length in miles

Where "U" is the $0.0949 cost per vehicle miles as determined above.

Introduction to Cost Estimates

In making the cost estimates presented herein it has been the intention of the Consultant to arrive at conservative cost estimates which will present each route alternate in as equitable and impartial manner as possible. Unit costs used in making these cost estimates were arrived at through a study of 1964 and 1965 Tabulation of Low Bid Prices for highway contracts let during these calendar years by the Montana State Highway Commission as well as Bid Tabulations for Interstate Highway Construction in this part of the State and on either side of this study area. Unit prices used are tabulated. No adjustment has been made for possible future general construction cost increases.

EARTHWORK

Unclassified Excavation	-	$0.32/Cubic Yard
Unclassified Borrow	-	0.36/Cubic Yard
Watering, Rolling and Earthwork Incidentals	-	0.07/Cubic Yard
Haul on Unclassified Excavation	-	0.11/Mile Yard
Haul on Borrow	-	0.02/Mile Yard

PAVEMENT

On the basis of the Typical Roadway Section-$1,350/Station

MISCELLANEOUS ITEMS

Controlled Access Fencing & Signing	$100/Station*
Other R/W Fencing	30/Station*
Guard Rail	280/Station*

*Length is actual length of fence or guard rail, not length of highway.

As discussed under the section entitled, "Major Underpass and Drainage Structures", reinforced concrete structures in this category have been estimated at $10.50 per Square Foot of overall area. The Unclassified Excavation price listed above is a composite price for earthwork of all classifications including a moderate amount of sandstone. This composite price has been weighed somewhat for estimates on the East End Hill Route and Thurmond Coulee Connection Route where, relatively speaking, more sandstone is likely to be encountered. Five percent of all construction cost items has been added for Preliminary Engineering and ten percent of these same items has been added for Construction Engineering and Contingencies. Utility Adjustment prices were worked out on the basis of typical costs requested and received from the utility section of the Montana State Highway Commission.

In figuring Annual Costs, the construction costs arrived at, as discussed above, were taken as capital improvement costs to be amortized at 6% compound interest with the following amortization periods:

Right-of-Way Damages and Utility Relocation	50 Years
Base and Surfacing, Guardrail, Fencing, Traffic Control Devices and Seeding	20 Years
All Other Items	40 Years

Maintenance costs were figured at $1,500 per year per mile for Interstate and $250 per year per mile for frontage roads. Because utility adjustment costs are not a contract construction item, they are included in the Right-of Way costs.

To breakdown construction costs into the various segments and thus show where the various overall construction items are concentrated, Plate 4 has been prepared and bound herewith. On this cost breakdown it has been necessary to somewhat arbitrarily assign earthwork costs to the various segments although in summing up these segments the total earthwork cost for each complete alternate will show the correct earthwork cost for that alternate. The segment earthwork breakdown is arbitrary because actually there is a slightly different earthwork cost for each segment depending on the route with which that segment is combined. Thus, in the interest of not making the segment cost tabulation any longer and more involved than necessary, Valley Route Segments common to other than the Valley Route were listed with the Valley Route earthwork costs. Likewise, Hill Route Segments common to other than the Hill Route were listed with Hill Route earthwork costs. The segments making the various connections between Valley and Hill Routes have been arbitrarily adjusted as to earthwork costs to make the overall route alternates involving the connections come out with the correct overall earthwork cost. Earthwork costs in the Valley Route segments where little, if any, unclassified excavation is involved have been based on the cost of borrow hauled into that segment to make the embankment involved therein.

On Plate 5, bound herewith., a segment by segment annual cost breakdown is shown to include amortization costs of capital improvements, including right-of-way, annual road user costs and annual maintenance costs.

Plate 1, bound with "Report Summary and Recommendations", summarizes the capital improvement costs (initial costs) and annual costs for all possible combinations of the route alternates presented in this report. On this Plate the three west end route alternates and four east end route alternates are combined into twelve overall "Alignment Alternates" for the "Total Initial" and "Total Annual" costs of Interstate Highway No. 94 throughout the entire length of this study. On this Plate the Consultant's recommended alignment for the overall length of this study is identified.

Cost Summary and Conclusions

Initial and annual cost data as tabulated on Plat 4 and 5 which follow and "Cost Summary of Alternate Alignments, Plate 1 bound with this report following page 10, certainly do not show a conclusive cost differentiation between the various alternates. While the Valley Alignment involves substantially lower construction costs that other alternates this cost advantage is largely offset by much higher right-of-way and related costs. The alternates lowest on initial costs, including right-of-way and related items, are slightly longer than the other alternates herein considered. Thus road user costs tend to change the cost relationship picture when amortization of initial costs, maintenance costs and road user costs are combined for a comparison of annual costs. In this case narrowing the field of alternates on the basis of annual costs seems valid because the selections thus made involve alternates which are no more than 2% higher on initial costs than the longer alternates which have the lowest initial cost.

Thus, on the basis of cost comparisons tabulated on Plate I, overall alignments CE, the west Valley Route combined with Thurmond Coulee Connection for east end routing; AE, the west Hill Route combined with Thurmond Coulee Connection; CD, the west Valley Route combined with east Hill Route; and AD, the west and east Hill Routes combined are the alternate alignments deemed most worthy of consideration for selecting the recommended alighment. Because these four alignment alternates have a cost spread of less than 2% the decision relative to alighment recommendation cannot be made soley on the basis of tangible cost data present herein. Rather the decision must be made largely on the basis of indirect and intangible factors as are discussed on page 9 wherein the recommended alignment is identified.

Plate 4

CONSTRUCTION COST SUMMARY AND

ROUTE SEGMENT DESIGNATION	LENGTH (Miles)	EARTHWORK	FENCING SIGNING AND SEEDING	SURFACING AND GUARD RAIL	IRRIGATION AND DRAINAGE
H1-H2 V1-V2	2.42	$ 168,050	$ 32,141	$196,807	$111,364
H2-H3	3.68	351,610	47,697	287,923	109,567
H3-H4	2.38	152,940	30,156	193,275	69,921
H4-H5	4.94	520,430	66,280	389,890	167,378
H5-H6	3.04	435,970	40,286	250,006	79,574
H6-H7	2.22	160,400	28,094	187,574	59,975
H7-H8	2.51	92,620	30,151	198,025	37,591
V2-V3	1.46	45,080	18,152	108,013	40,302
V3-V4	4.57	231,135	58,658	360,910	123,542
V4-V5	4.94	494,680	66,023	389,890	167,378
V5-V6	1.82	125,955	23,576	158,509	41,078
V6-V7	0.76	29,990	9,467	54,068	20,702
V7-V8	5.28	335,490	67,727	423,899	174,734
V3-H3	2.27	205,545	29,487	178,893	55,122
V6-H6	1.21	196,540	16,368	104,925	40,897
V7-H7	2.82	251,230	36,423	230,679	58,213

COMPARISON OF ALTERNATES STUDIED

Plate 4

UNDERPASSES AND FRONTAGE ROADS	UTILITY RELOCATION	RIGHT-OF-WAY AND RELATED ITEMS	PRELIMINARY ENGINEERING	CONSTRUCTION ENGINEERING AND CONTINGENCIES	* TOTAL COSTS
$138,773	$ 17,970	$ 75,555	$ 33,256	$66,511	$ 840,427
95,444	4,950	31,566	44,860	89,719	1,063,336
51,640	11,300	12,892	25,462	50,923	598,509
114,298	18,050	38,859	71,166	142,333	1,675,684
21,440	1,500	39,485	41,439	82,878	992,578
29,180	600	6,040	23,291	46,582	541,736
10,000	4,000	17,341	18,619	37,239	445,586
63,392	800	16,565	13,787	27,574	333,665
202,580	70,547	136,352	52,369	104,737	1,340,830
114,298	18,050	38,859	69,866	139,732	1,645,776
85,020	1,800	29,960	21,797	43,594	531,289
32,281	600	16,305	7,355	14,711	185,479
188,081	14,050	84,679	60,199	120,398	1,469,257
81,679	1,200	33,860	27,597	55,193	668,576
5,083	------	21,773	18,196	36,381	440,163
95,226	600	21,416	33,619	67,237	794,643

*Total costs include $147,000 for REST AREA in addition to other Initial Cost Items shown for Route Segments H4-H5 and V4-V5.

Plate 5

			ANNUAL
			CONSTR
ROUTE DESIGNATION	LENGTH (Miles)	UTILITY RELOCATION RIGHT-OF-WAY Est. 50 year life	Grading, Drainage & Major Structures Est. 40 year life
V1=H1 to V4=H4			
Hill Route - West Half	8.48	$ 9,785	$ 103,680
Mill Creek Route - West Half	8.53	10,794	98,634
Valley Route - West Half	8.45	20,161	94,536
V4=H4 to V8=H8			
Hill Route - East Half	12.71	7,986	155,477
Thurmond Coulee Route - East Half	12.70	8,782	150,398
Sand Creek Route - East Half	12.85	9,448	150,002
Valley Route - East Half	12.80	12,961	161,786

Plate 5

COST

UCTION Surfacing & Guard Rail Estimated 20 year life	MAINTENANCE Interstate $1500 per Mile	 Frontage Roads $250 per Mile	OPERATING COSTS	TOTAL ANNUAL COST
68,698	12,720	423	$1,513,324	$1,708,630
68,604	12,795	680	1,522,247	1,713,754
67,537	12,675	1,780	1,507,970	1,704,659
103,771	19,065	337	2,228,127	2,514,763
104,889	19,050	700	2,226,374	2,510,193
104,338	19,275	1,035	2,252,669	2,536,767
104,020	19,200	1,640	2,243,904	2,543,511

FIGURE 12

PLAN-PROFILE LEGEND

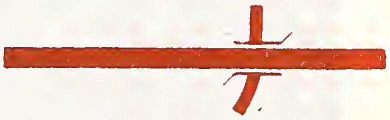
PLAN DATA

SCALE: 1" = 500'

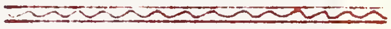
ALTERNATE ALIGNMENTS: HILL ROUTE 🟥
VALLEY ROUTE 🟩
CONNECTIONS 🟦

FRONTAGE ROADS, ACCESS ROADS, AND REST AREA 🟥

UNDERPASSES



CHANNEL CHANGE



D = DEGREE OF CURVATURE, SIMPLE CURVE

PROFILE DATA

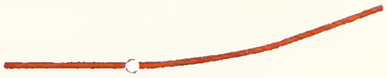
SCALES: HORIZONTAL 1" = 500', VERTICAL 1" = 50'

WESTBOUND

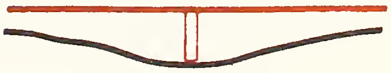
GROUND LINE ⬛
GRADE LINE: HILL ROUTE 🟥
VALLEY ROUTE 🟩
CONNECTIONS 🟦

V. C. = VERTICAL CURVE

POINT OF CURVATURE OR POINT OF TANGENCY ON THE VERTICAL CURVE



UNDERPASS, TYPE I OR II



UNDERPASS OR DRAINAGE S. P. P. C., C. M. P. OR R. C. P.

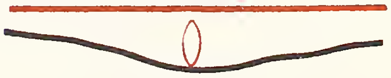
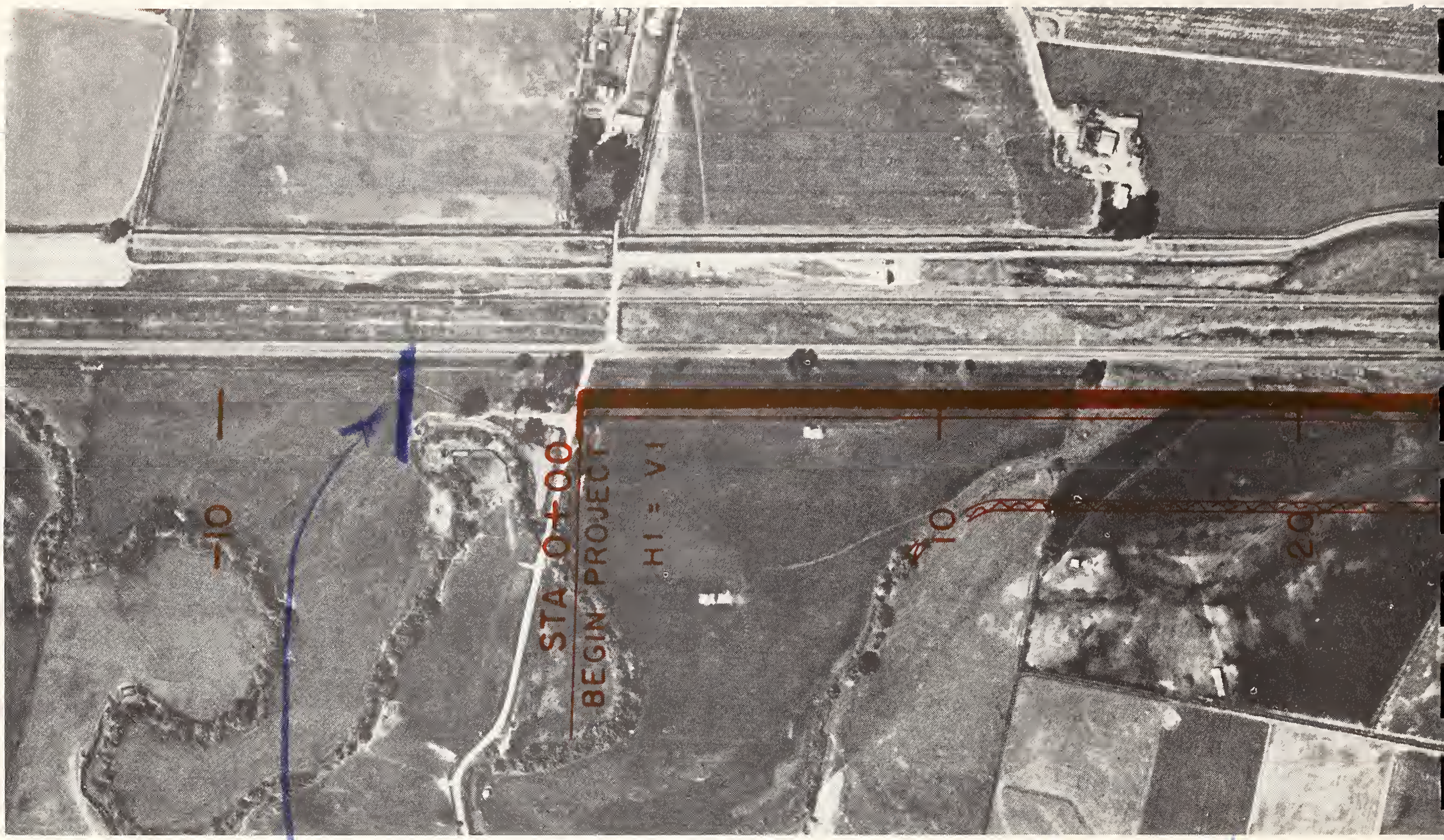


FIGURE 13



begin design at aprox sta -5±
total length aprox 19.5 mi

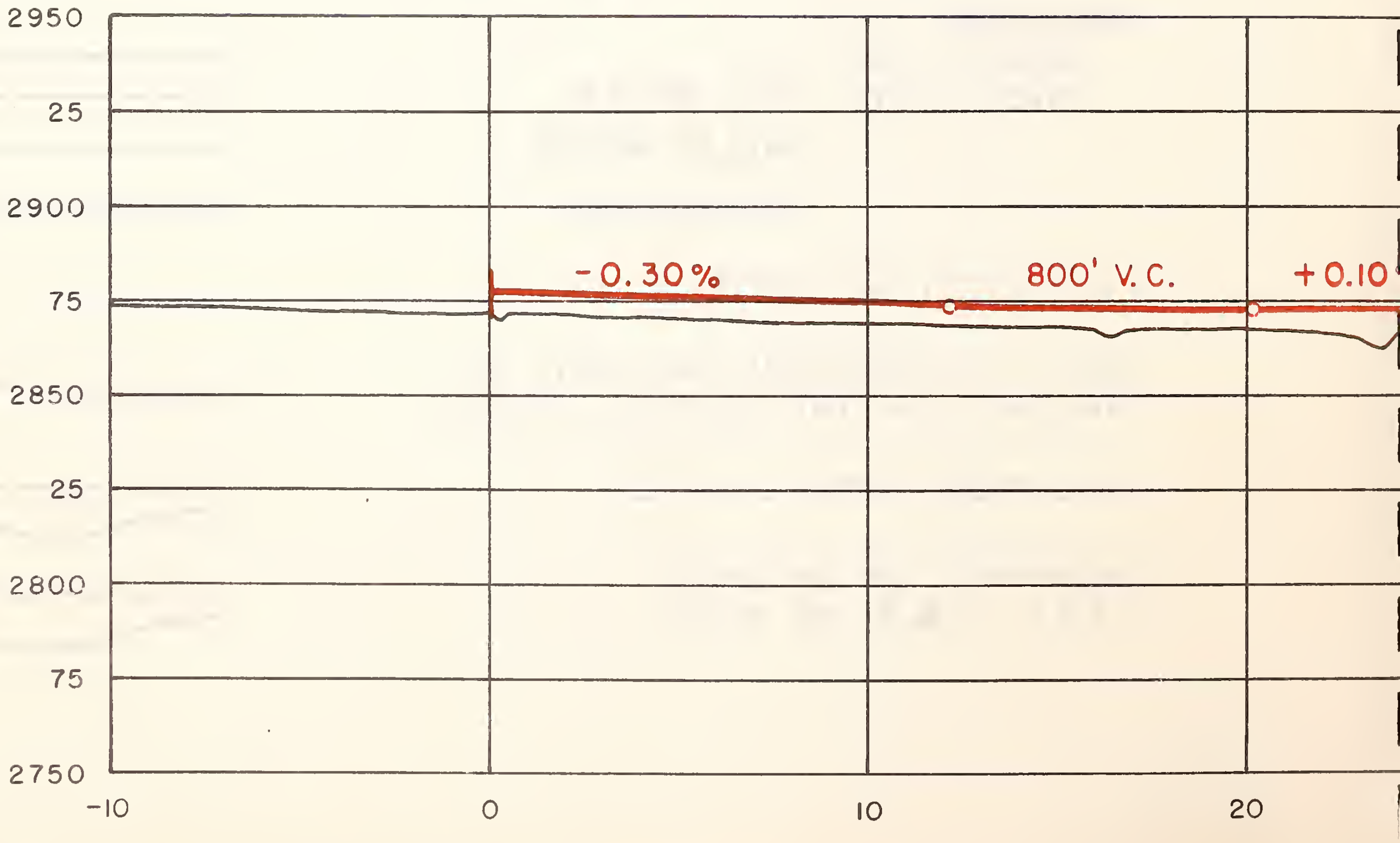


FIGURE 14

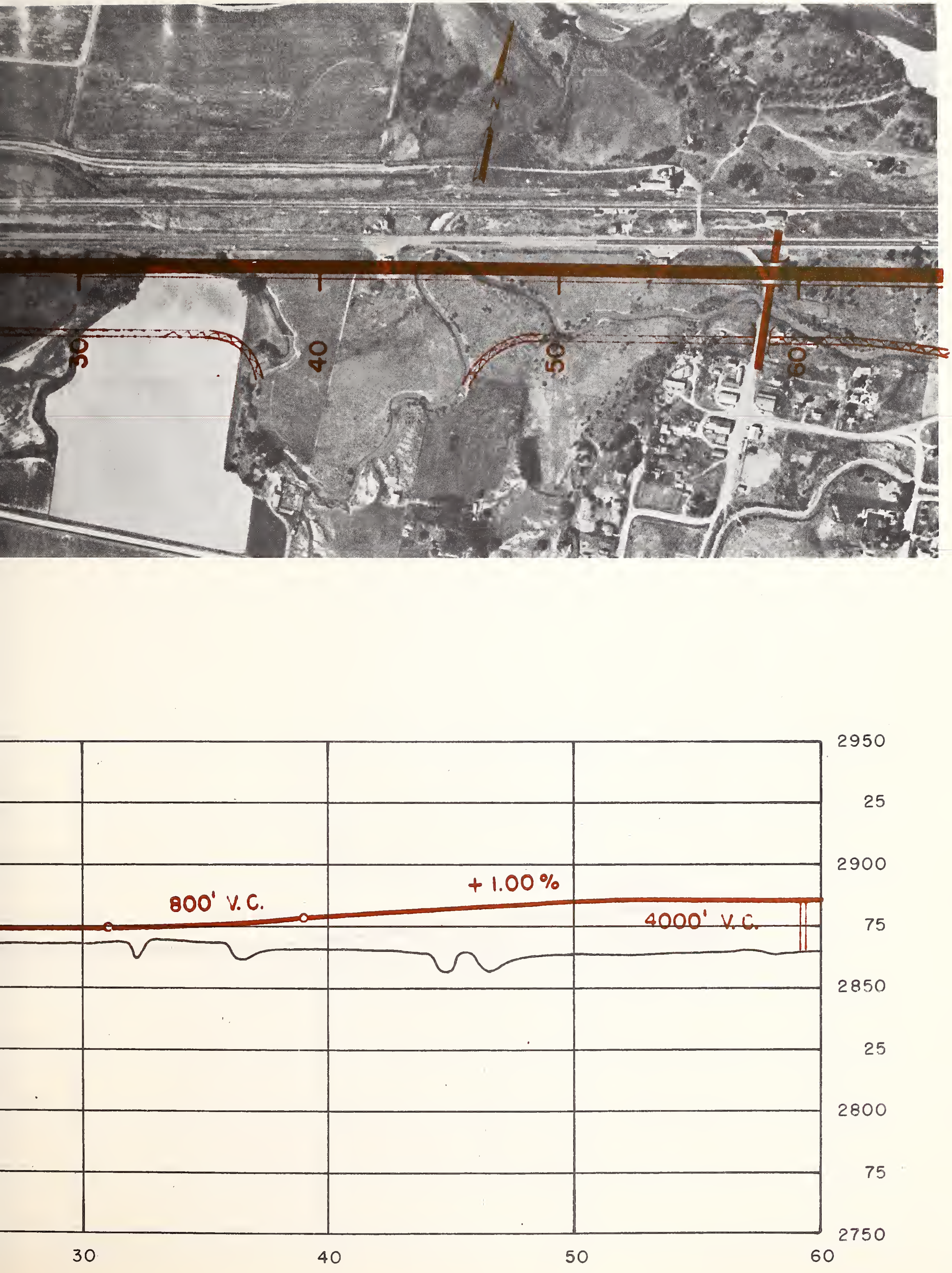

N
30
40
50
60
800' V. C.
+ 1.00 %
4000' V. C.
2950
25
2900
75
2850
25
2800
75
2750
30
40
50
60

FIGURE 15

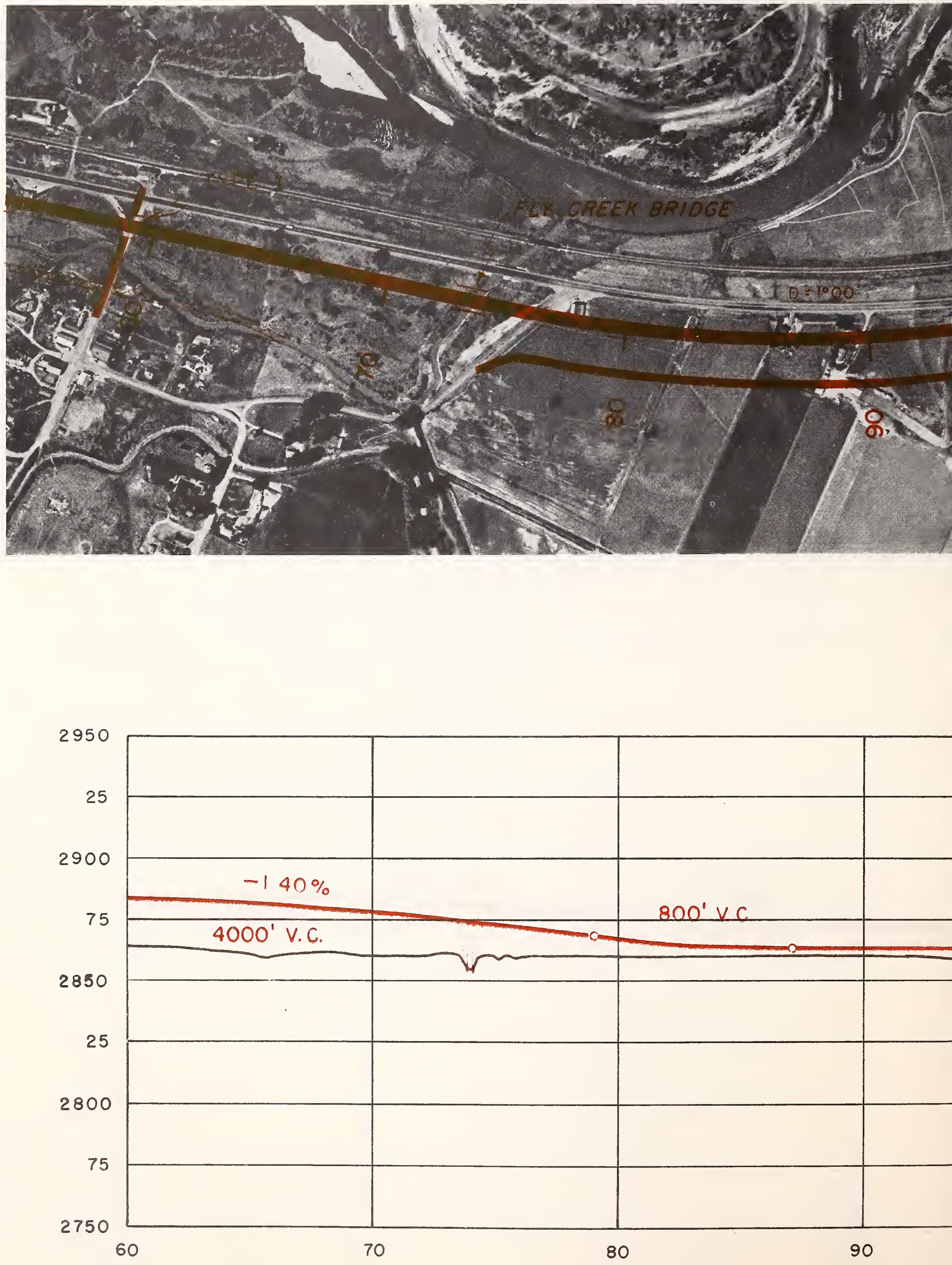

FLY CREEK BRIDGE
D = 1°00'
70
80
90
2950
25
2900
75
2850
25
2800
75
2750
60
70
80
90
−1 40%
4000' V.C.
800' V.C

FIGURE 16

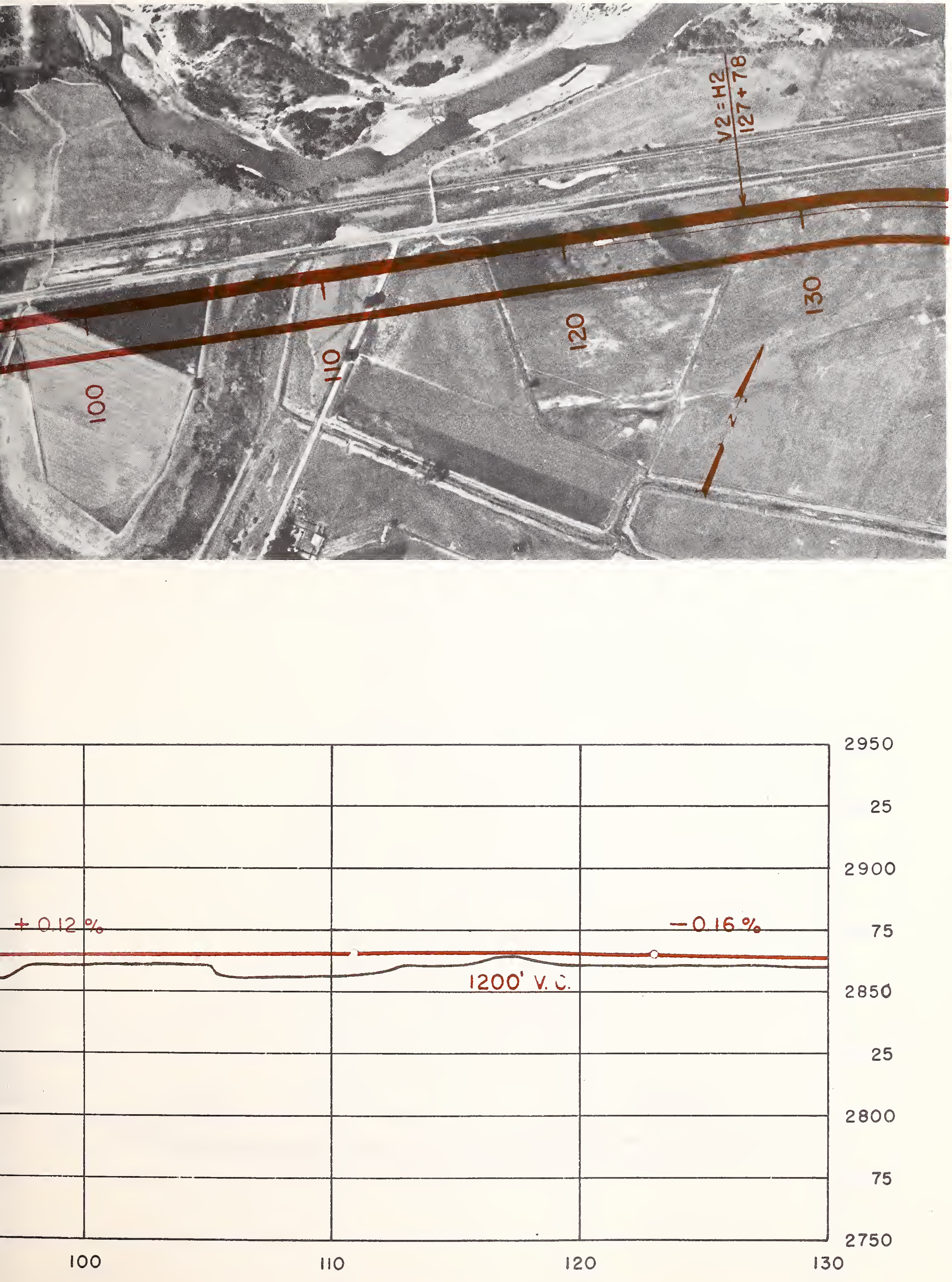
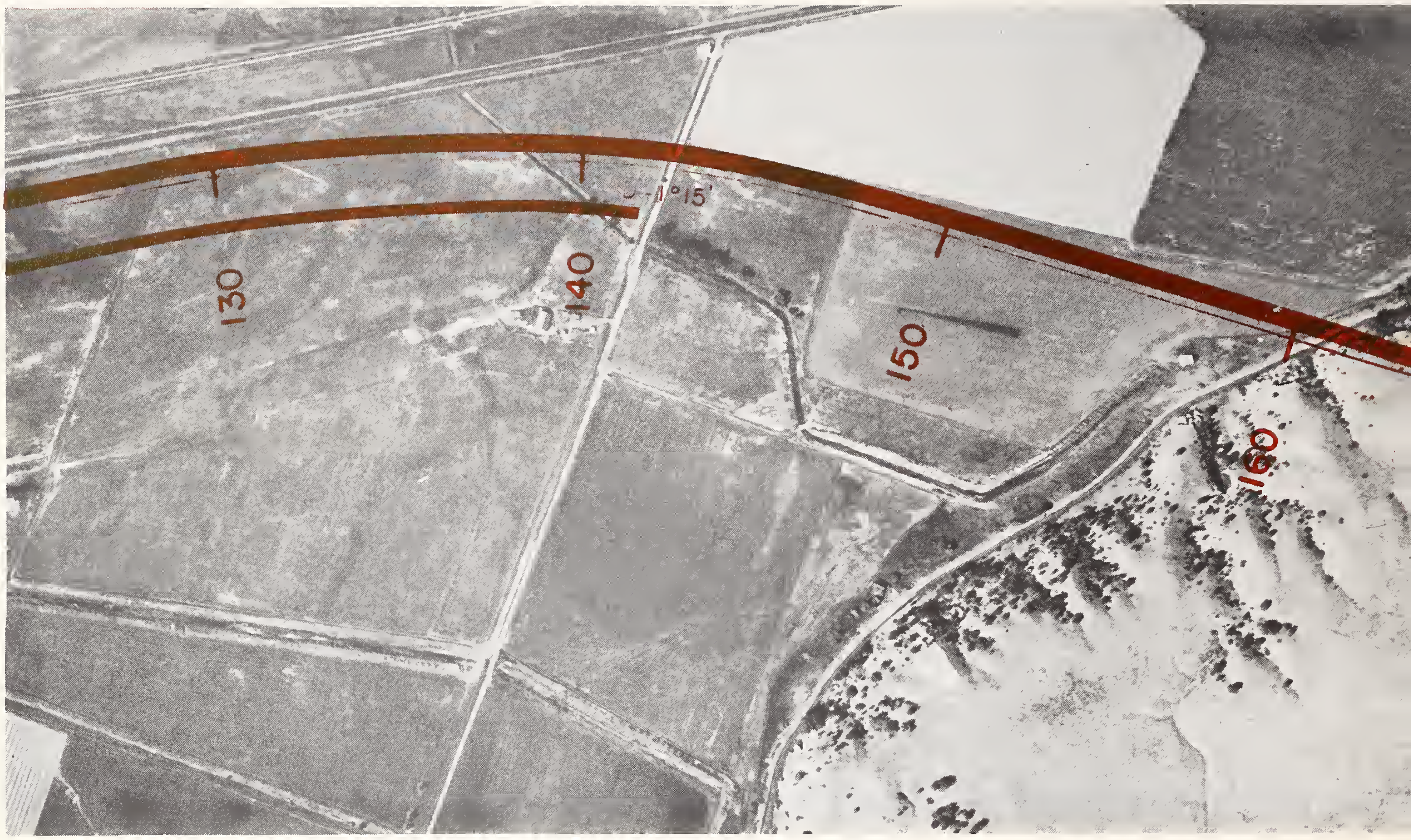

V2=H2
127+78
100
110
120
130
N
+0.12 %
−0.16 %
1200' V.C.
2950
25
2900
75
2850
25
2800
75
2750
100
110
120
130

FIGURE 17


1°15'
130
140
150
160

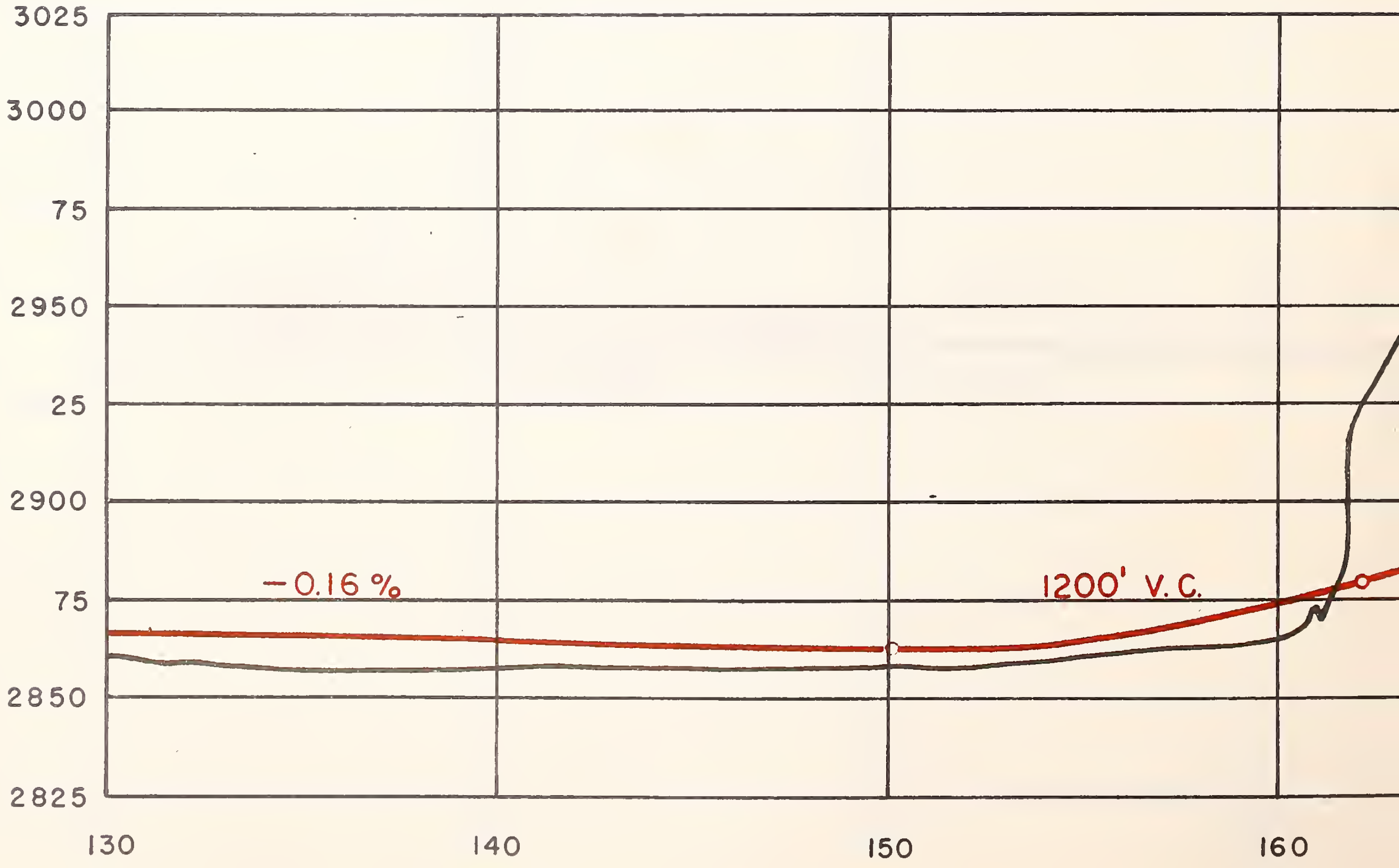

3025
3000
75
2950
25
2900
75
2850
2825
−0.16 %
1200' V. C.
130
140
150
160

FIGURE 18

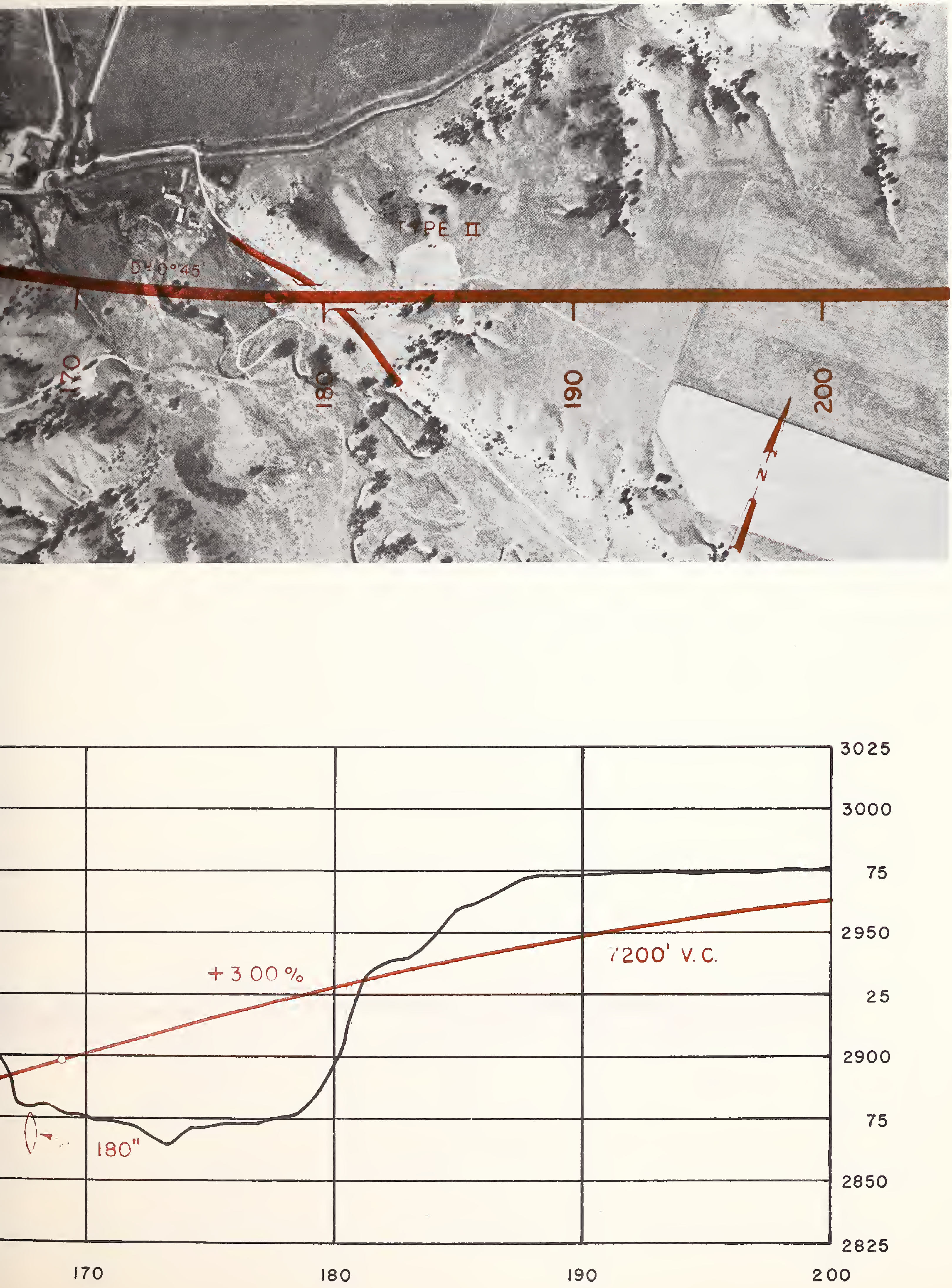

TYPE II
D=0°45'
170
180
190
200
N
3025
3000
75
2950
25
2900
75
2850
2825
+3.00%
7200' V.C.
180"
170
180
190
200

FIGURE 19

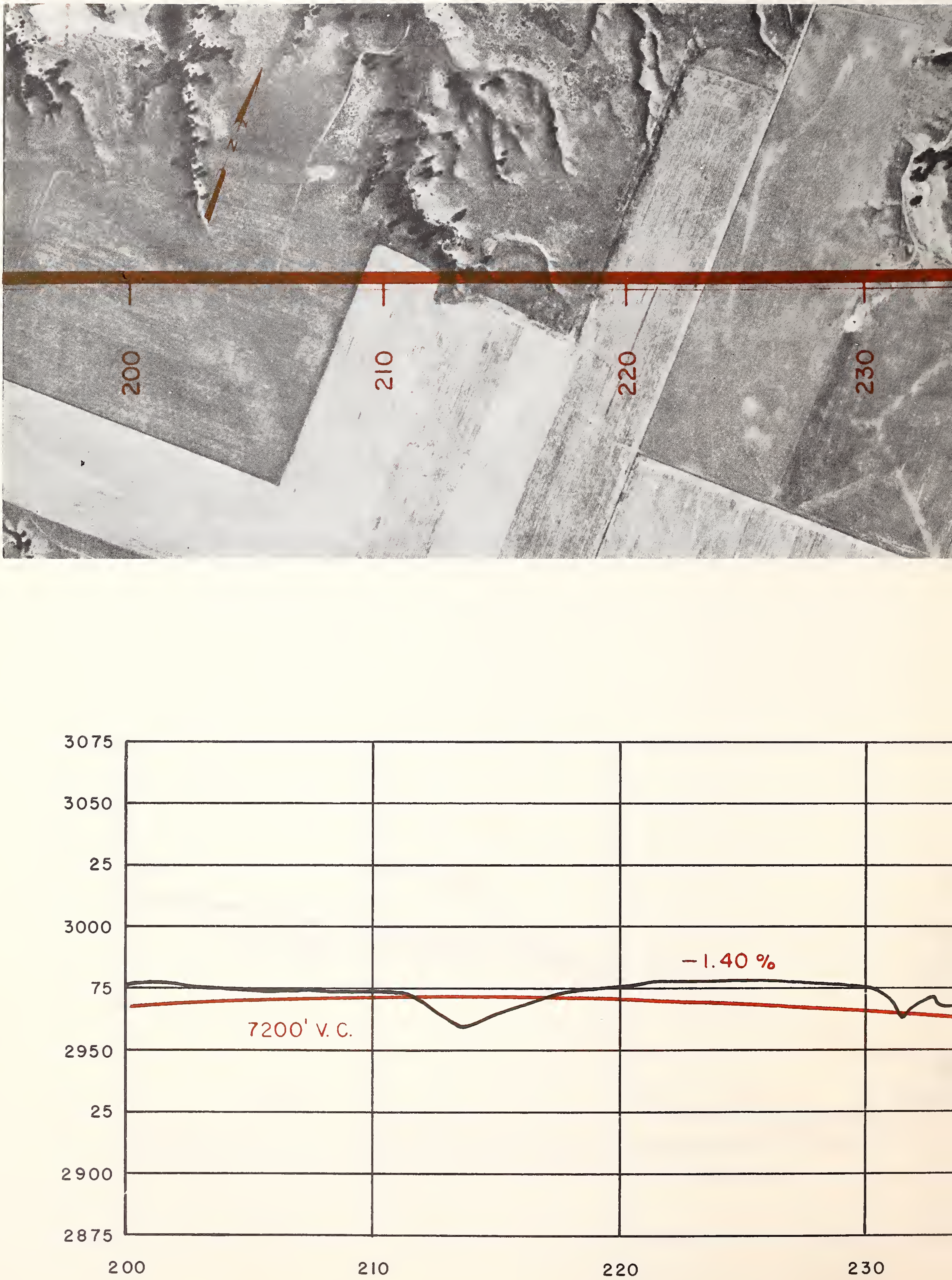
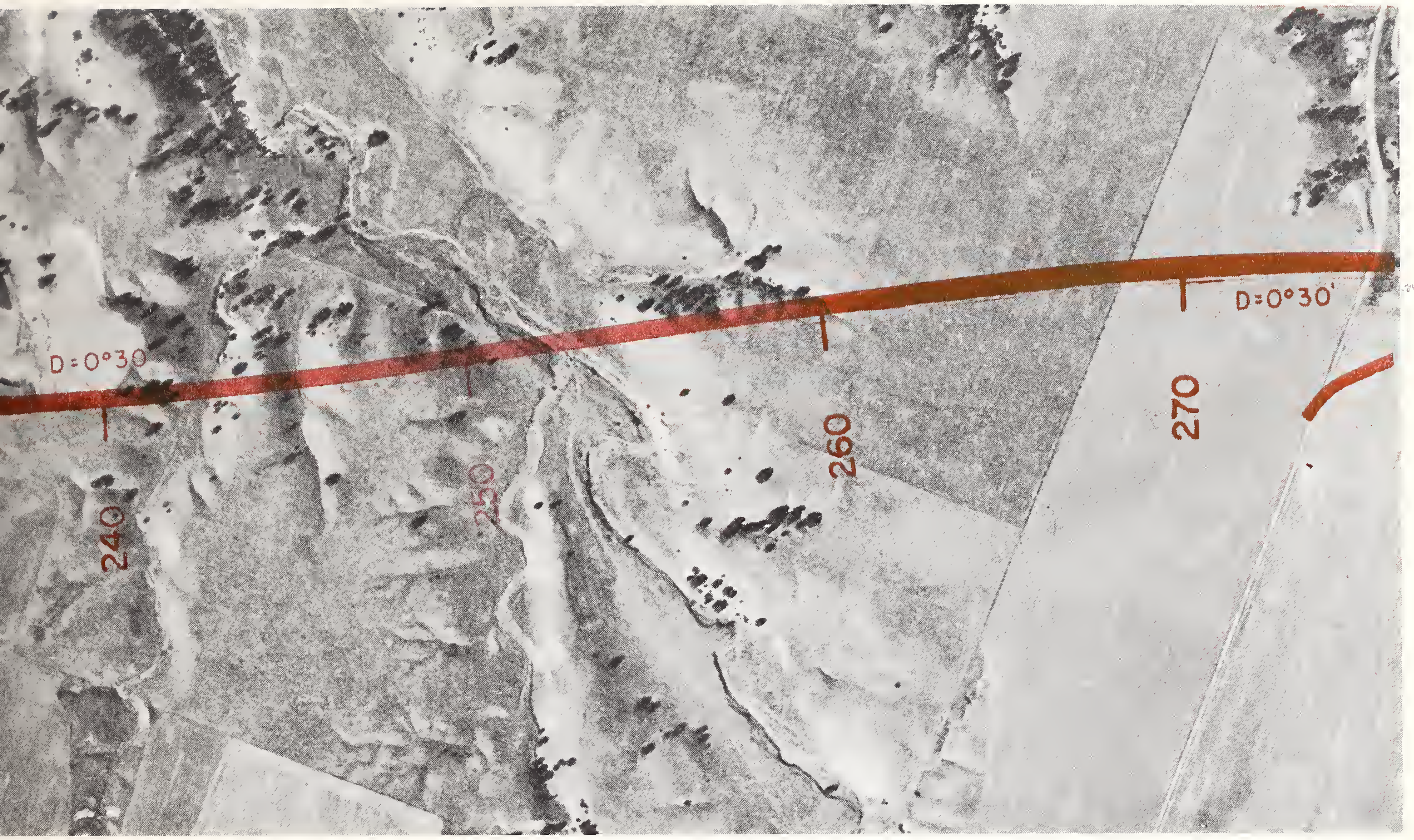

N
200
210
220
230
3075
3050
25
3000
75
2950
25
2900
2875
−1.40 %
7200' V. C.
200
210
220
230

FIGURE 20


D=0°30
240
250
260
270
D=0°30'

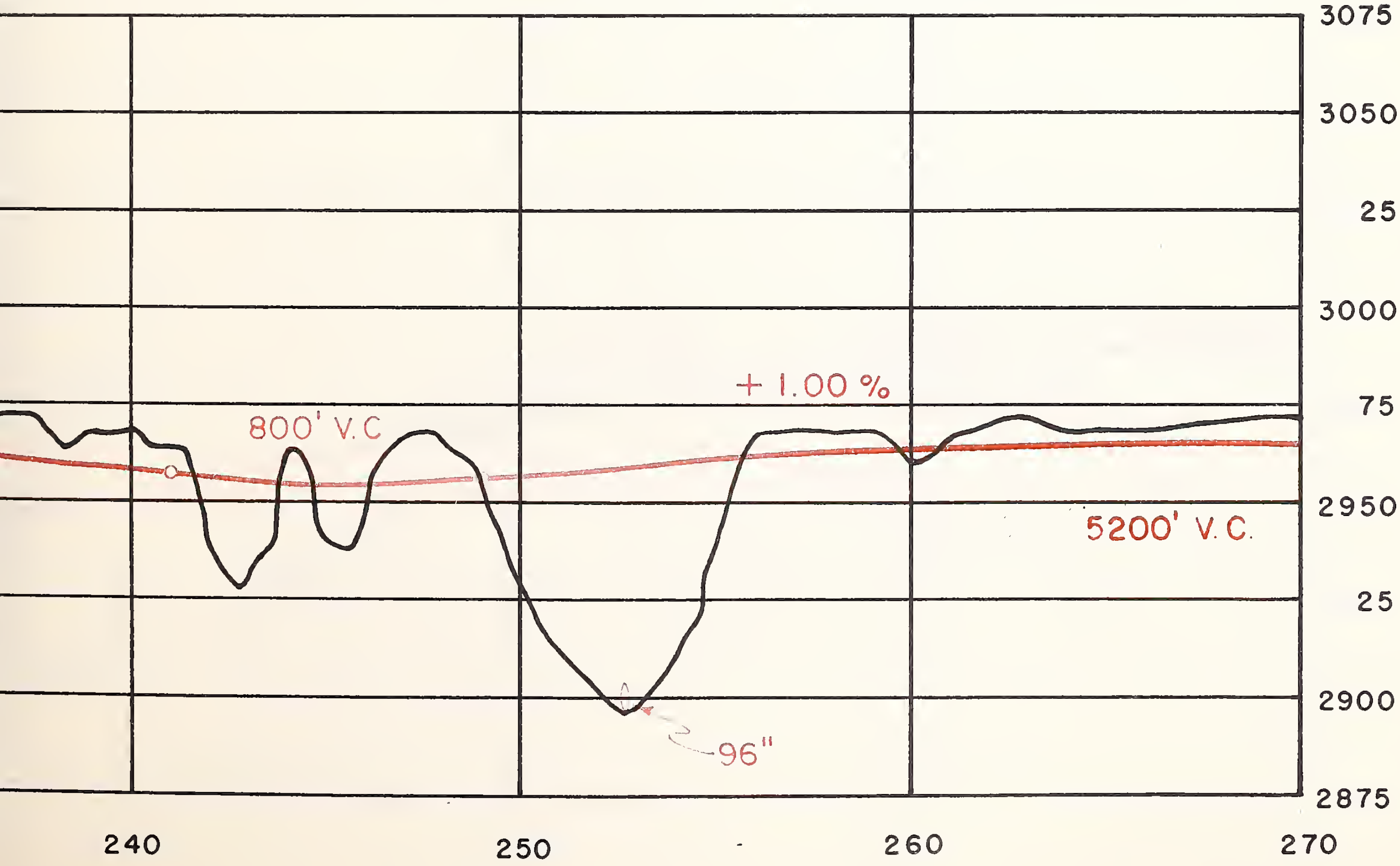

3075
3050
25
3000
75
2950
25
2900
2875
+ 1.00 %
800' V.C
5200' V.C.
96"
240
250
260
270

FIGURE 21

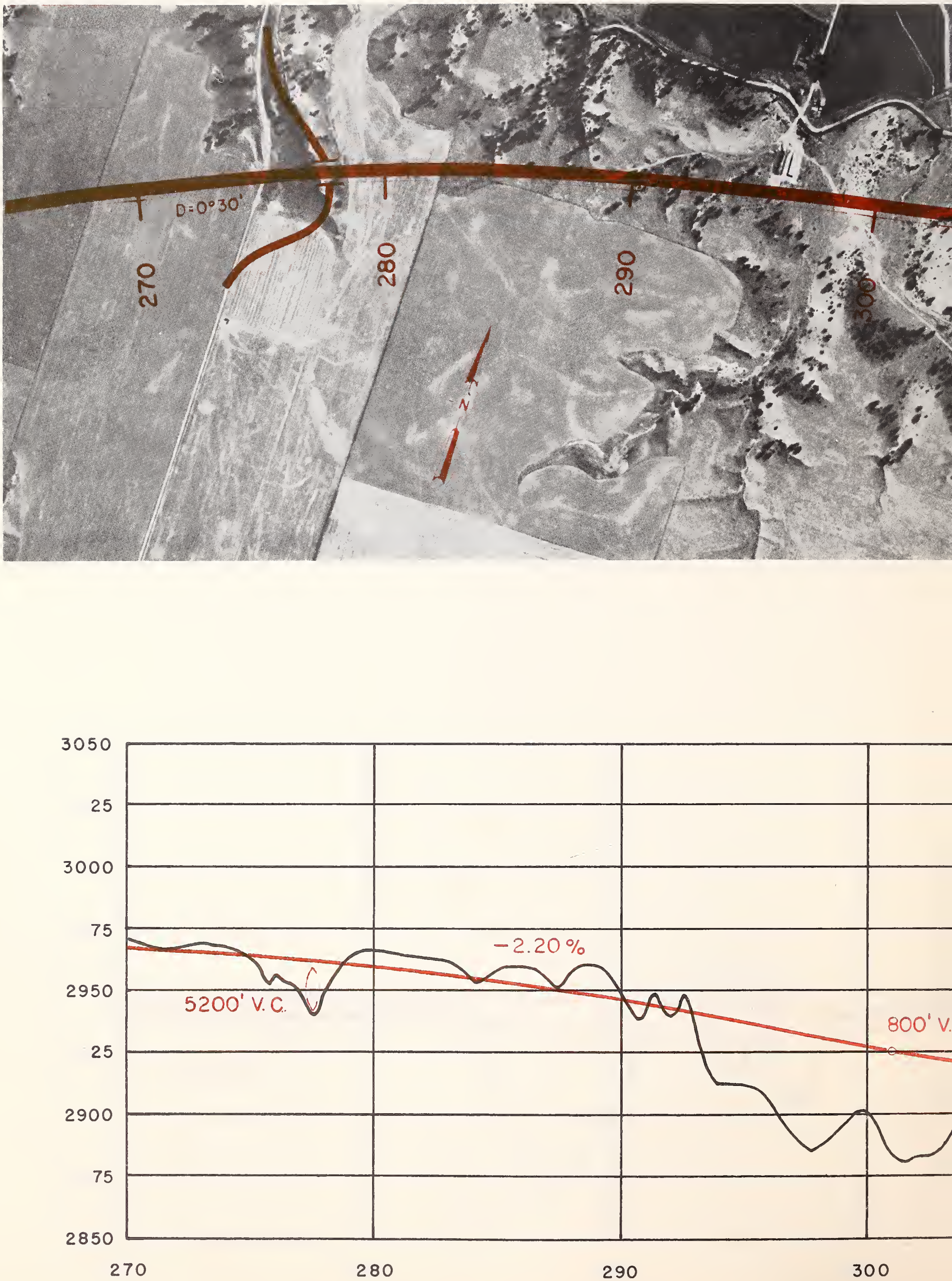
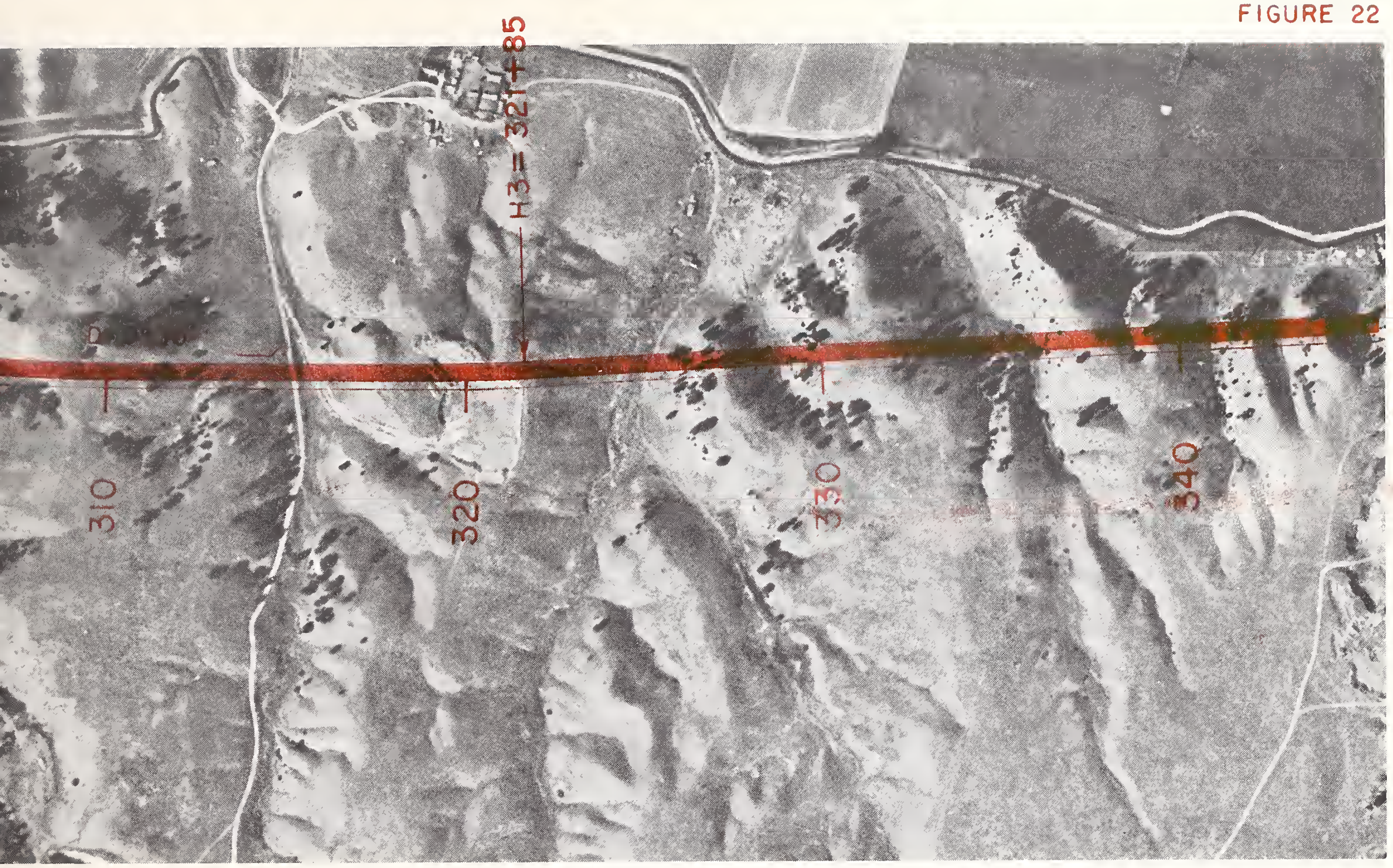

D=0°30'
270
280
290
300
N
3050
25
3000
75
2950
25
2900
75
2850
270
280
290
300
−2.20 %
5200' V.C.
800' V.

FIGURE 22


H3= 321+85
310
320
330
340

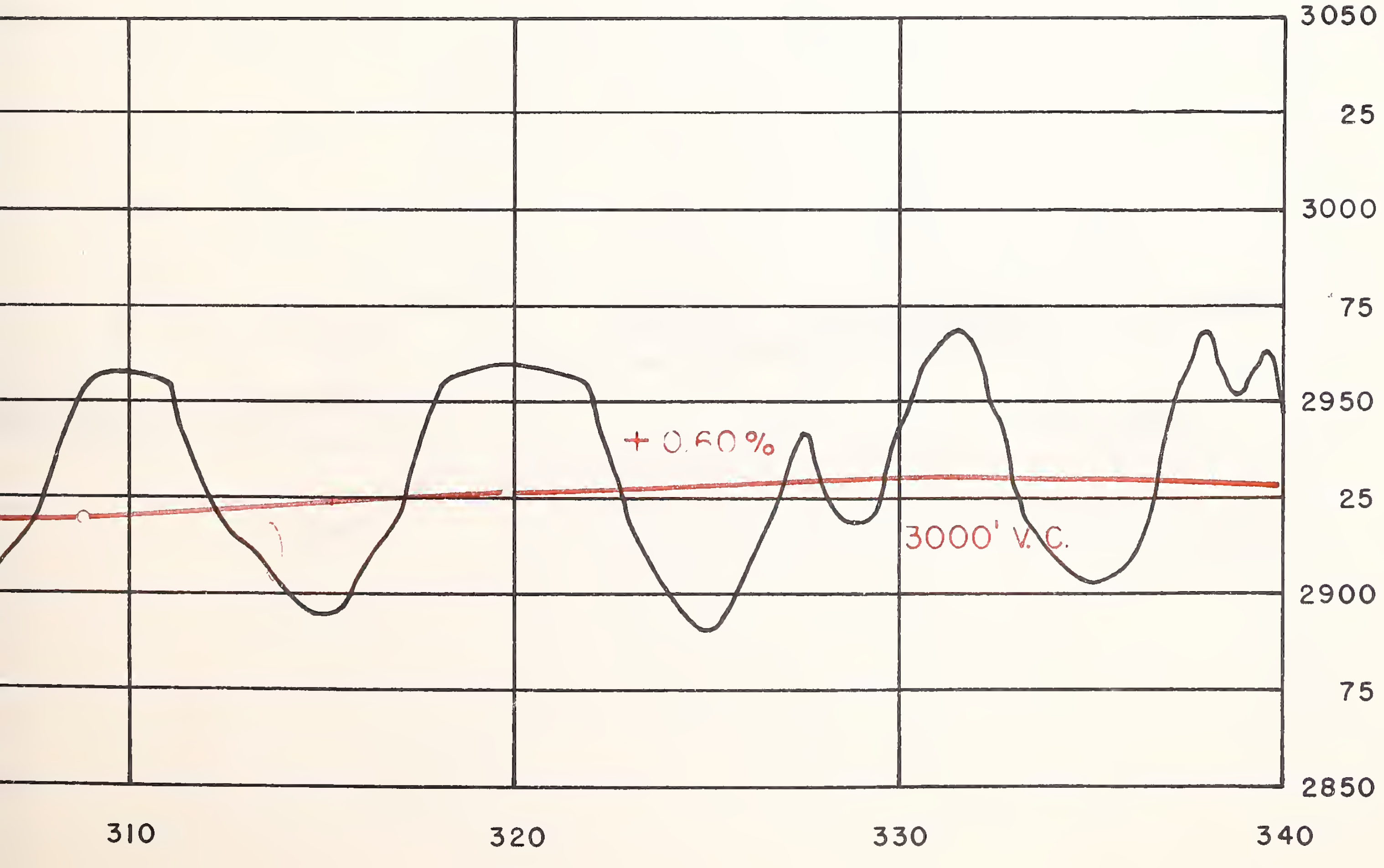

3050
25
3000
75
2950
25
2900
75
2850
+ 0.60 %
3000' V.C.
310
320
330
340

FIGURE 23

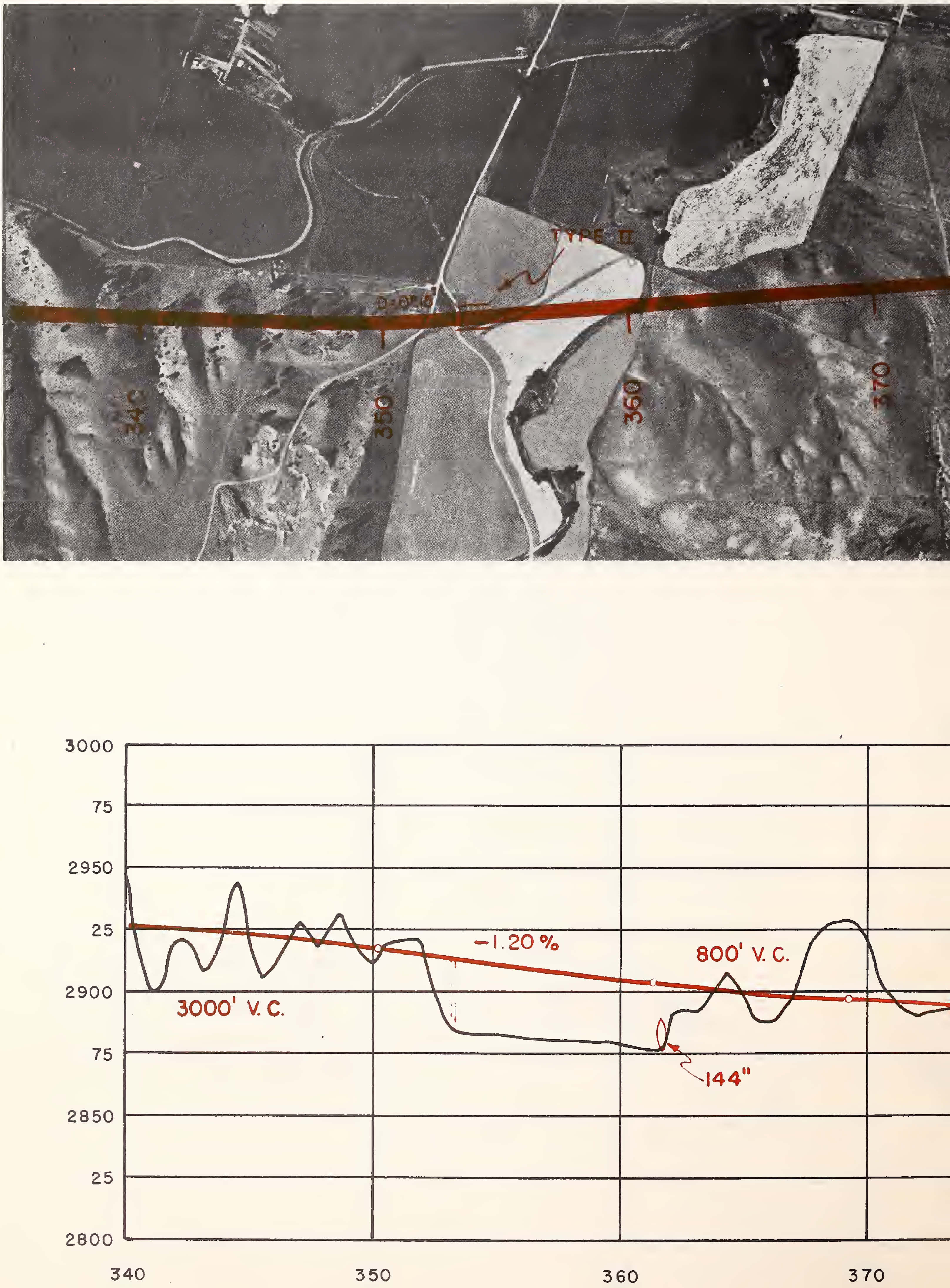

TYPE II
D-0°15'
340
350
360
370
3000
75
2950
25
2900
75
2850
25
2800
-1.20 %
800' V. C.
3000' V. C.
144"
340
350
360
370

FIGURE 24

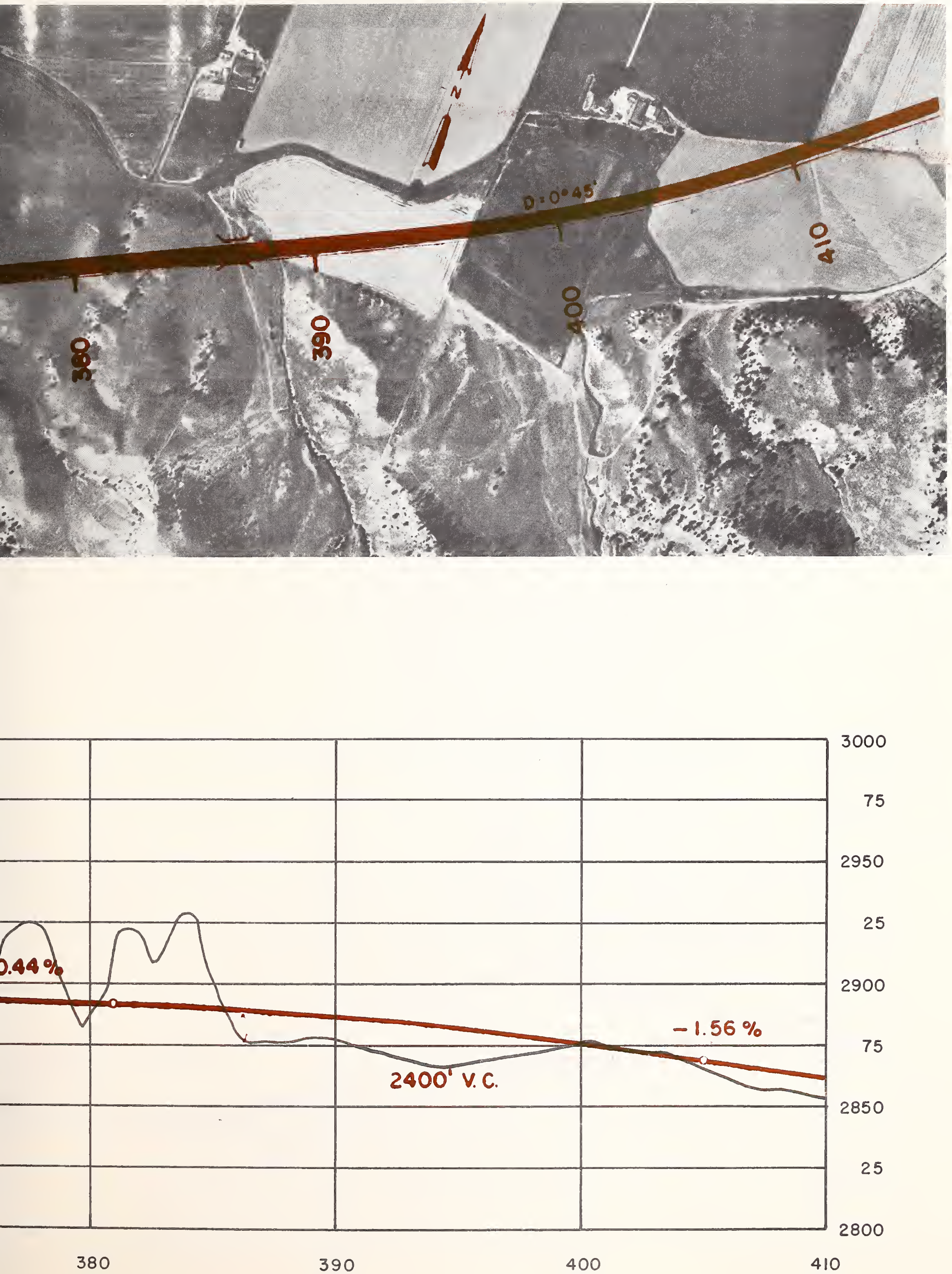

N
D=0°45'
380
390
400
410
3000
75
2950
25
2900
75
2850
25
2800
.44 %
– 1.56 %
2400' V. C.
380
390
400
410

FIGURE 25

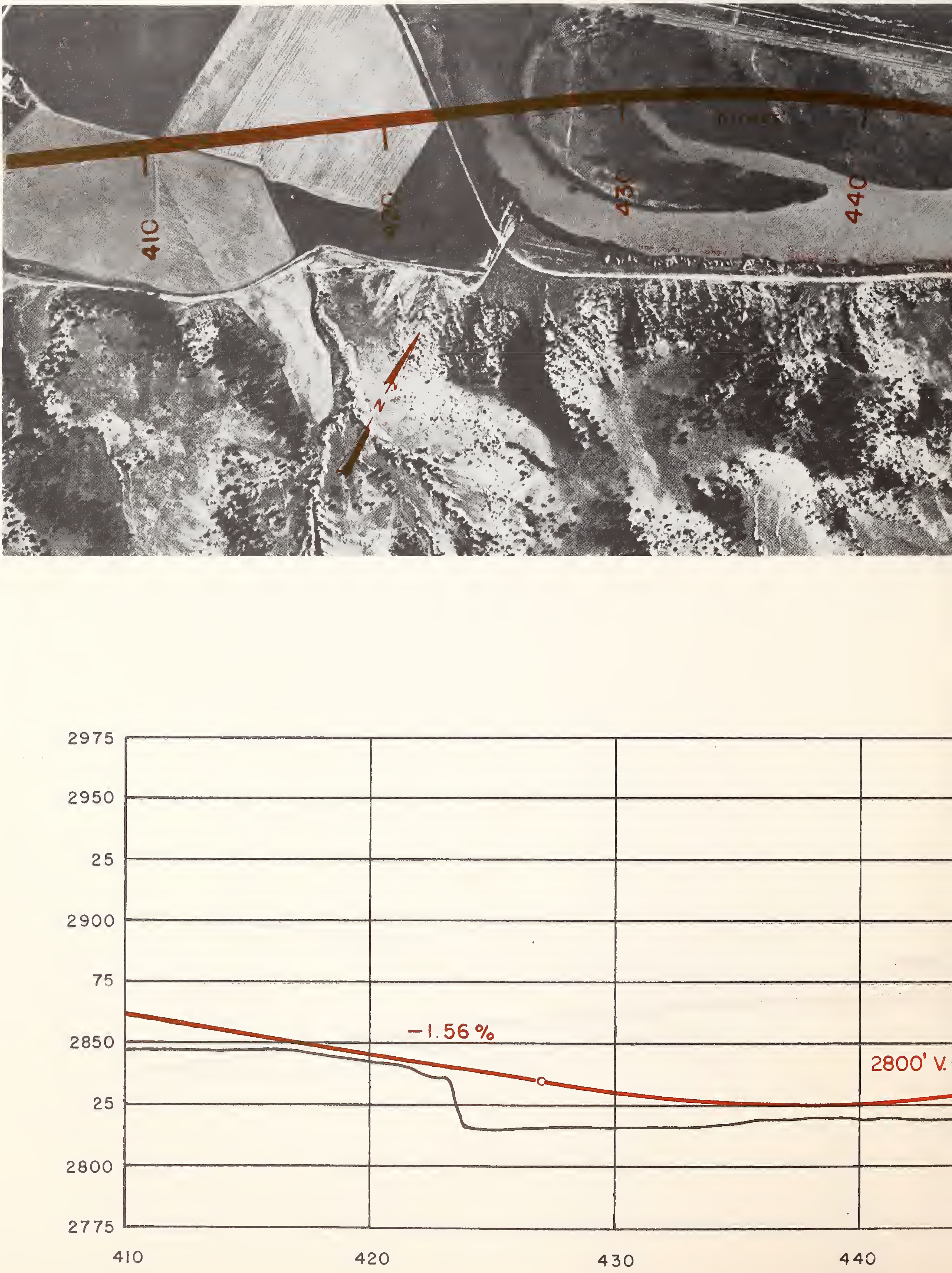

410
420
430
440
N
2975
2950
25
2900
75
2850
25
2800
2775
−1.56 %
2800' V.
410
420
430
440

FIGURE 26

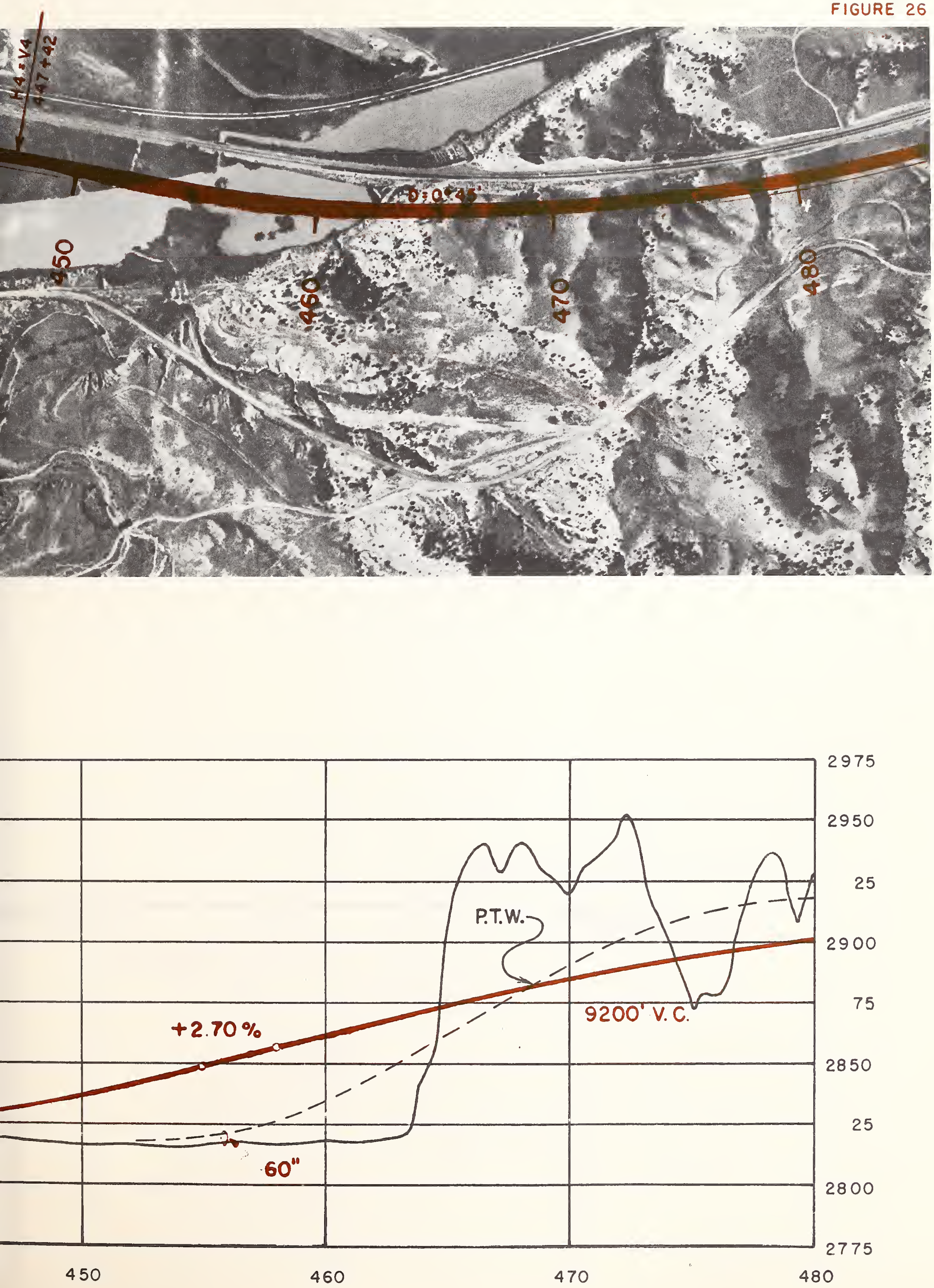

H4=V4
447+42
D=0°45'
450
460
470
480
2975
2950
25
2900
75
2850
25
2800
2775
P.T.W.
+2.70 %
9200' V.C.
60"
450
460
470
480

FIGURE 27

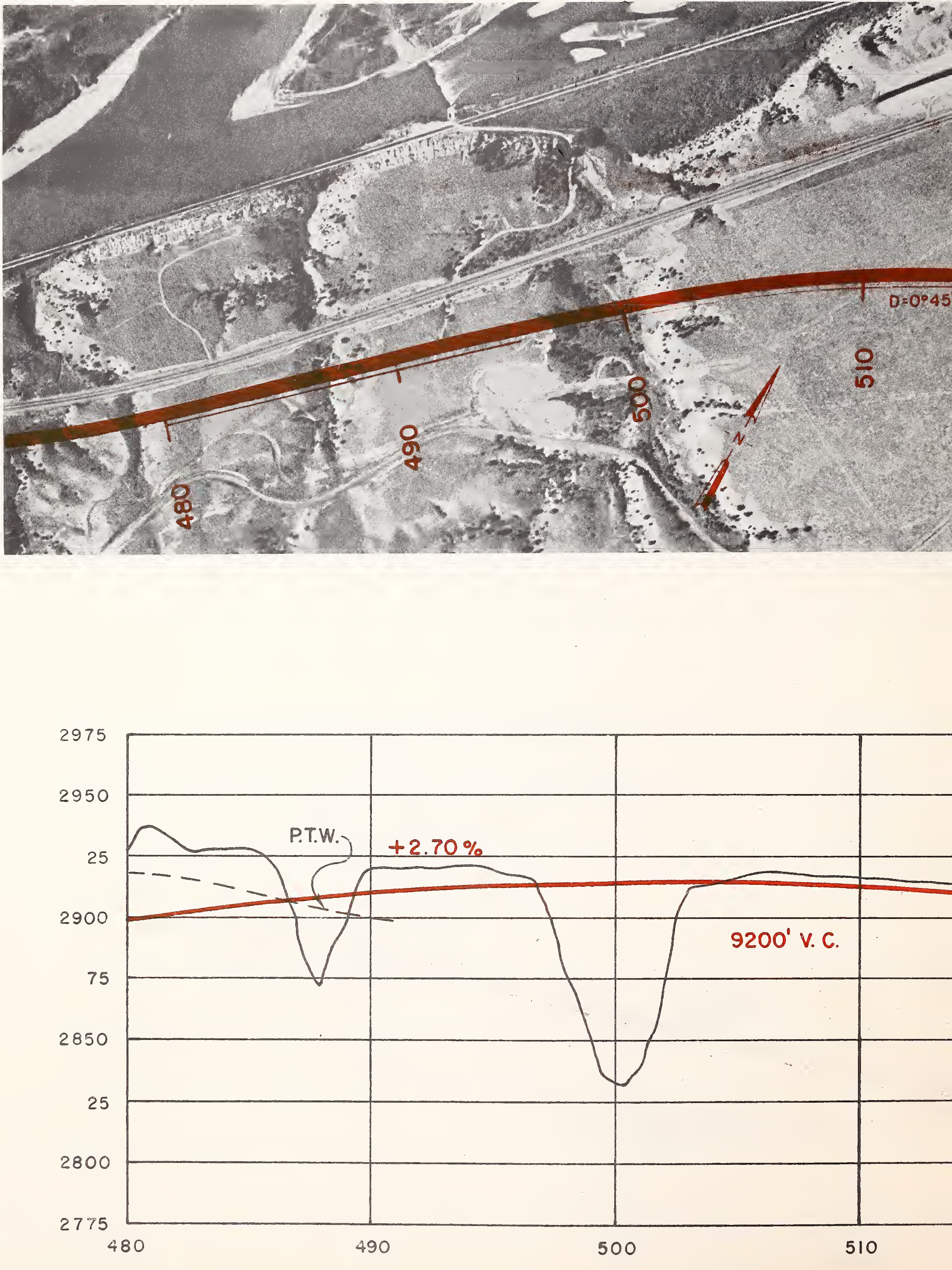
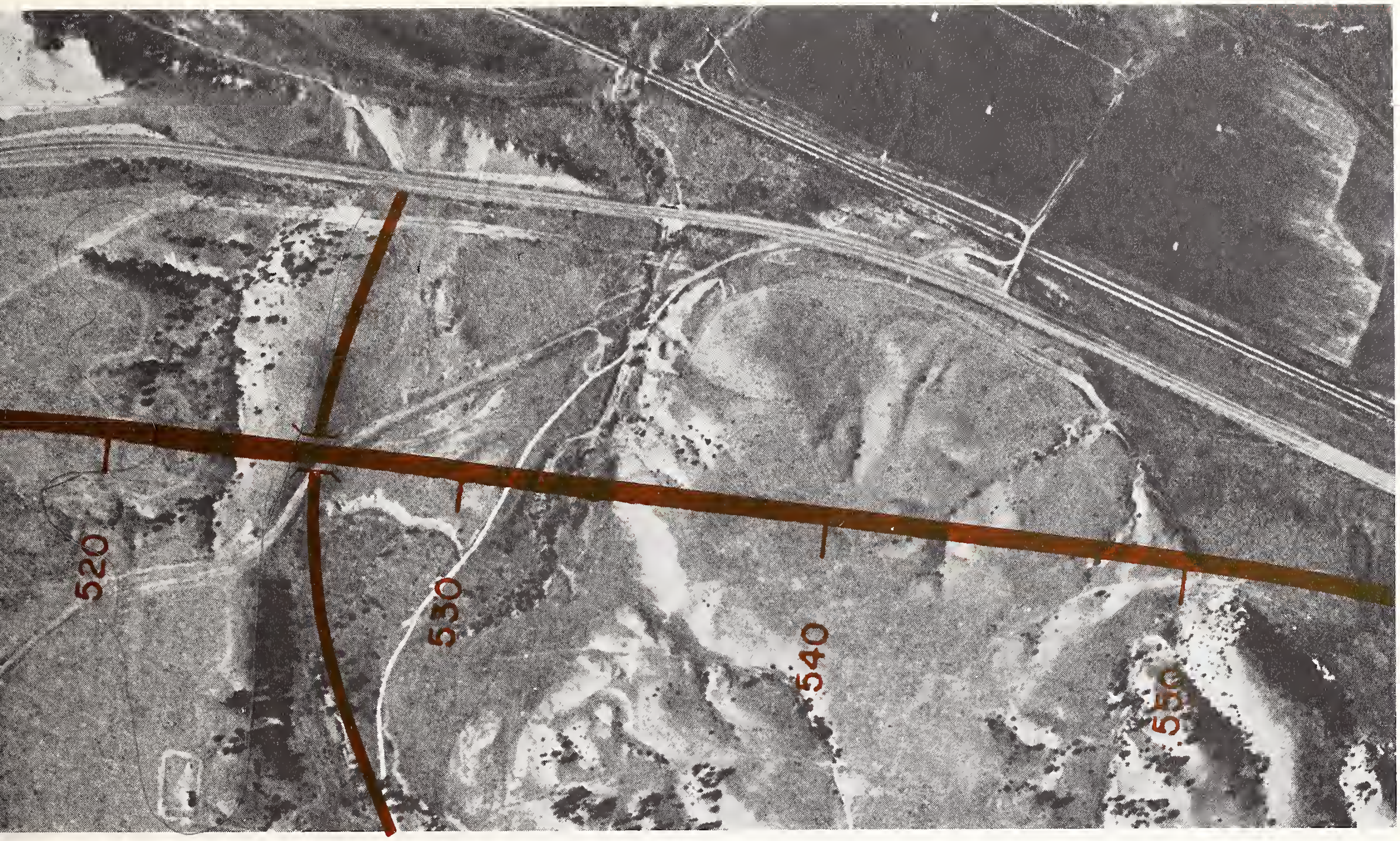
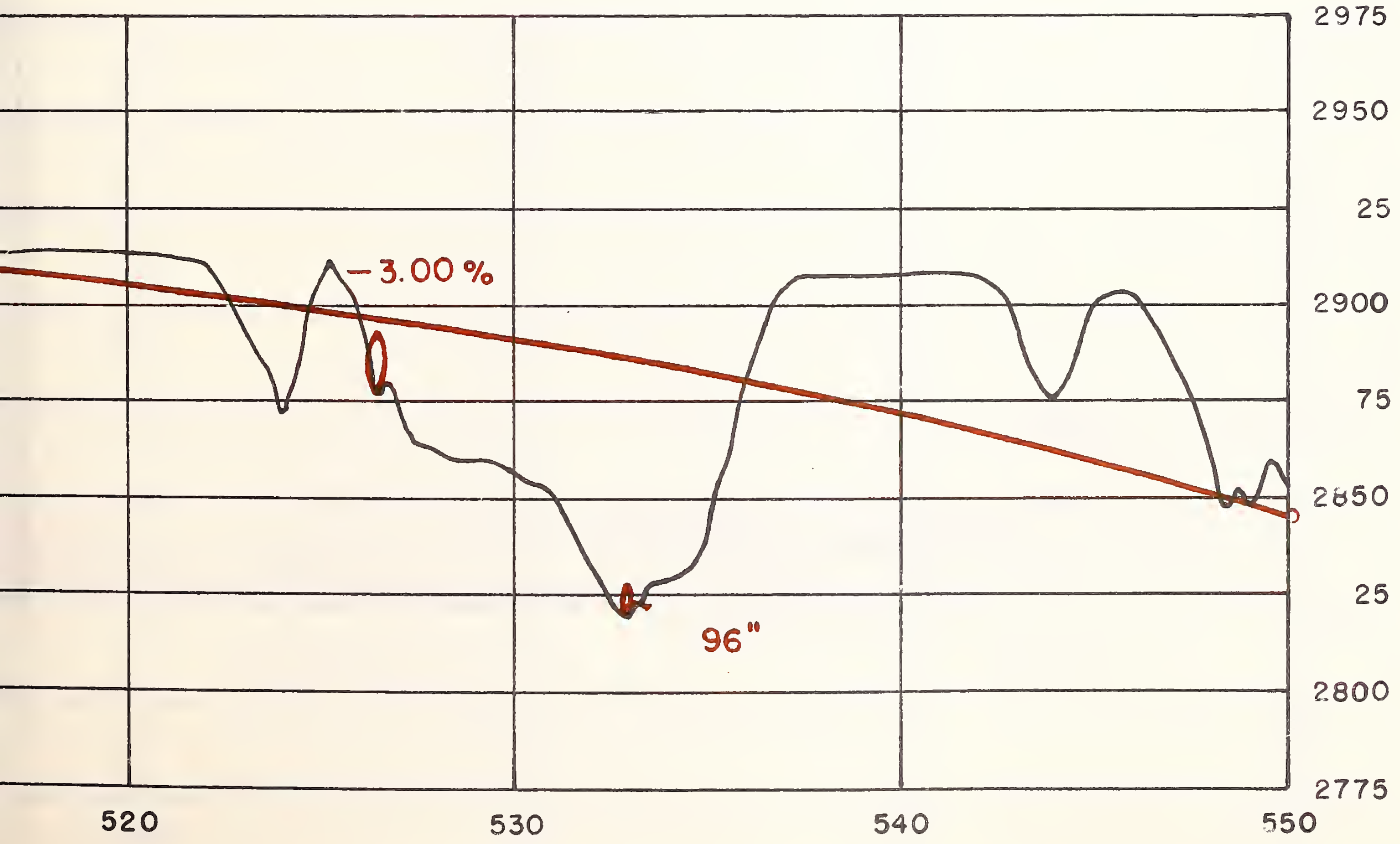

D=0°45
510
500
490
480
N
2975
2950
25
2900
75
2850
25
2800
2775
P.T.W.
+2.70 %
9200' V. C.
480
490
500
510

FIGURE 28



520
530
540
550



-3.00 %
96"
2975
2950
25
2900
75
2850
25
2800
2775
520
530
540
550

FIGURE 29

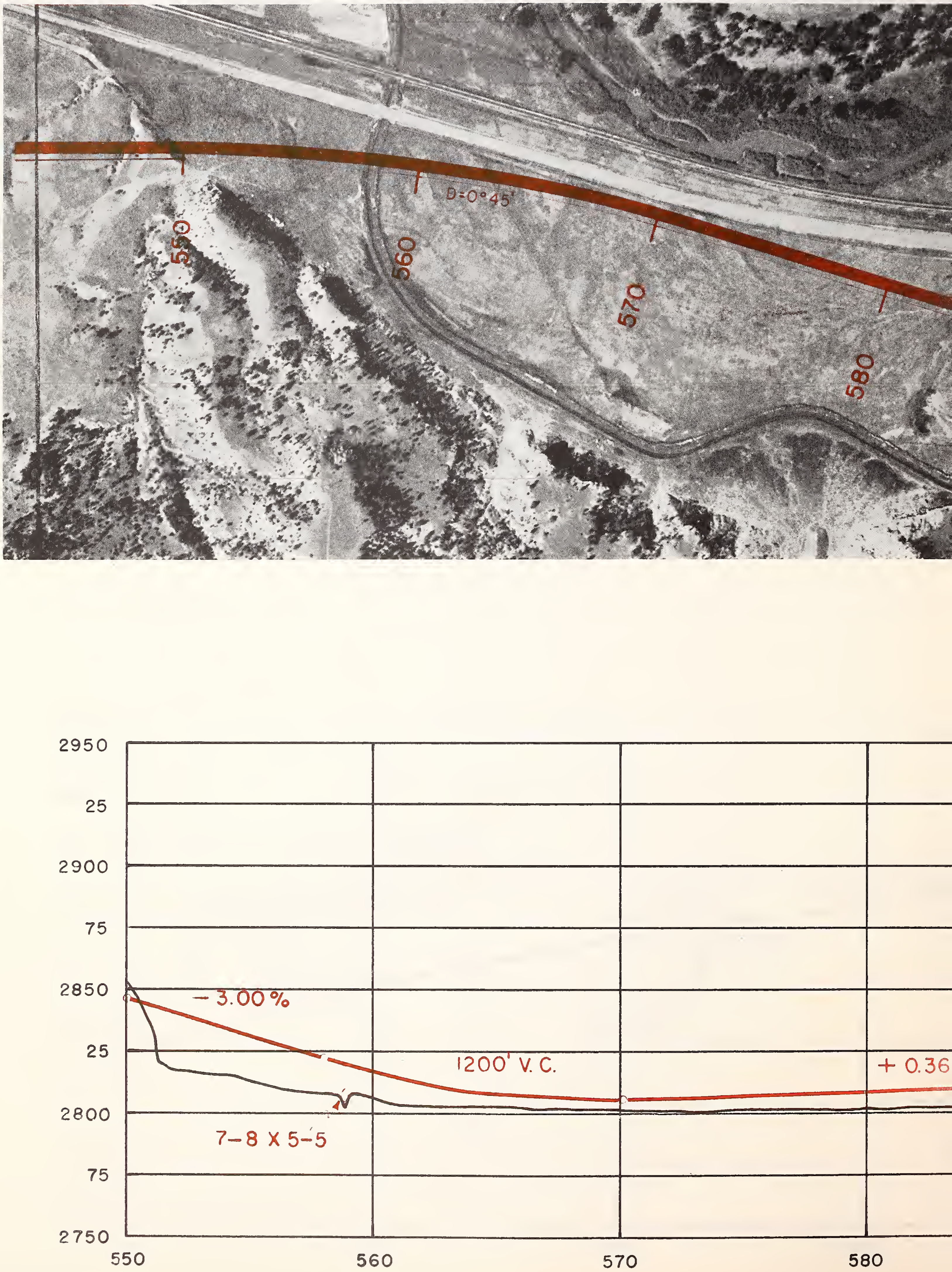

D=0°45'
550
560
570
580
2950
25
2900
75
2850
25
2800
75
2750
− 3.00 %
1200' V. C.
+ 0.36
7−8 X 5−5
550
560
570
580

FIGURE 30

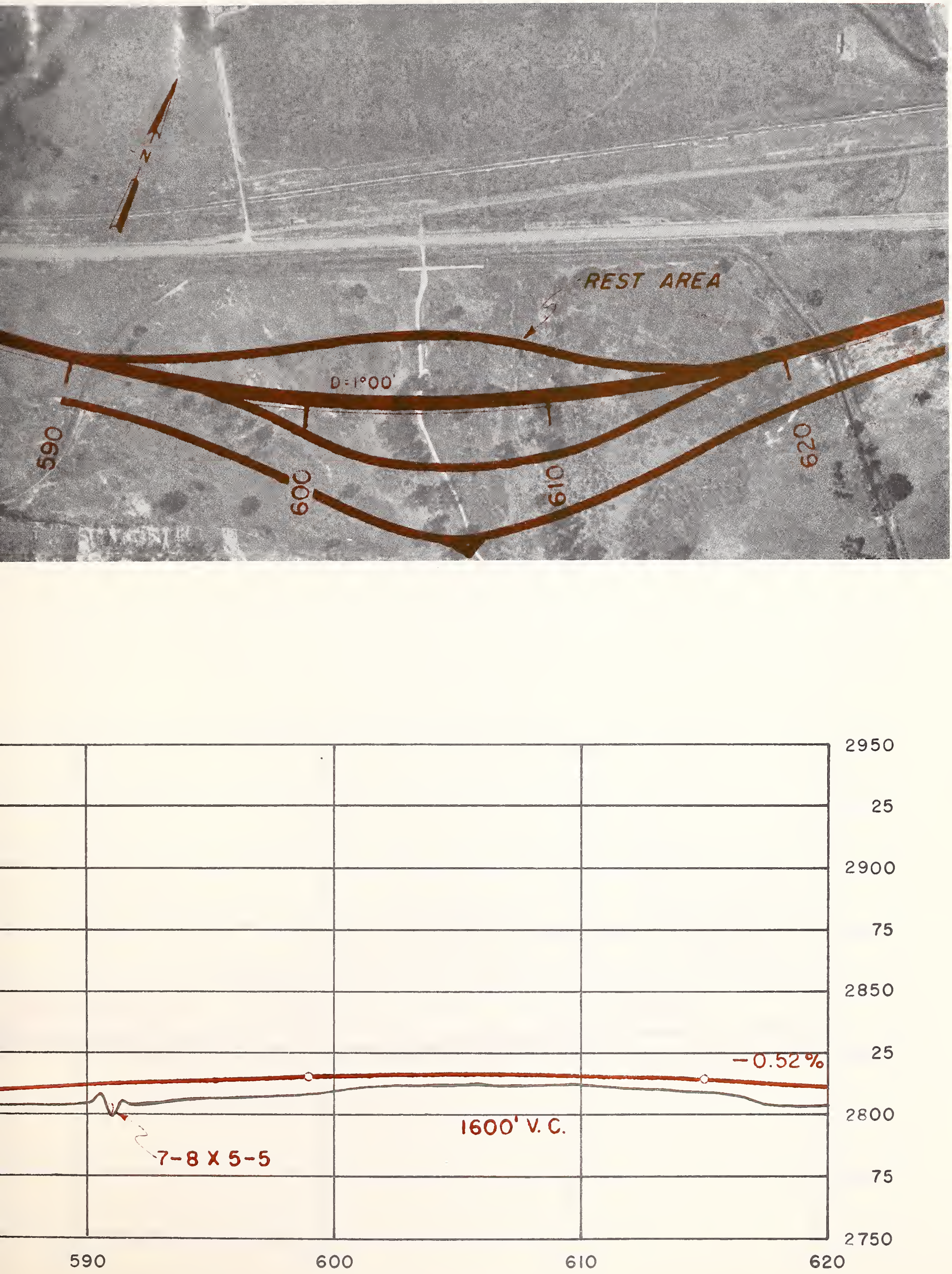
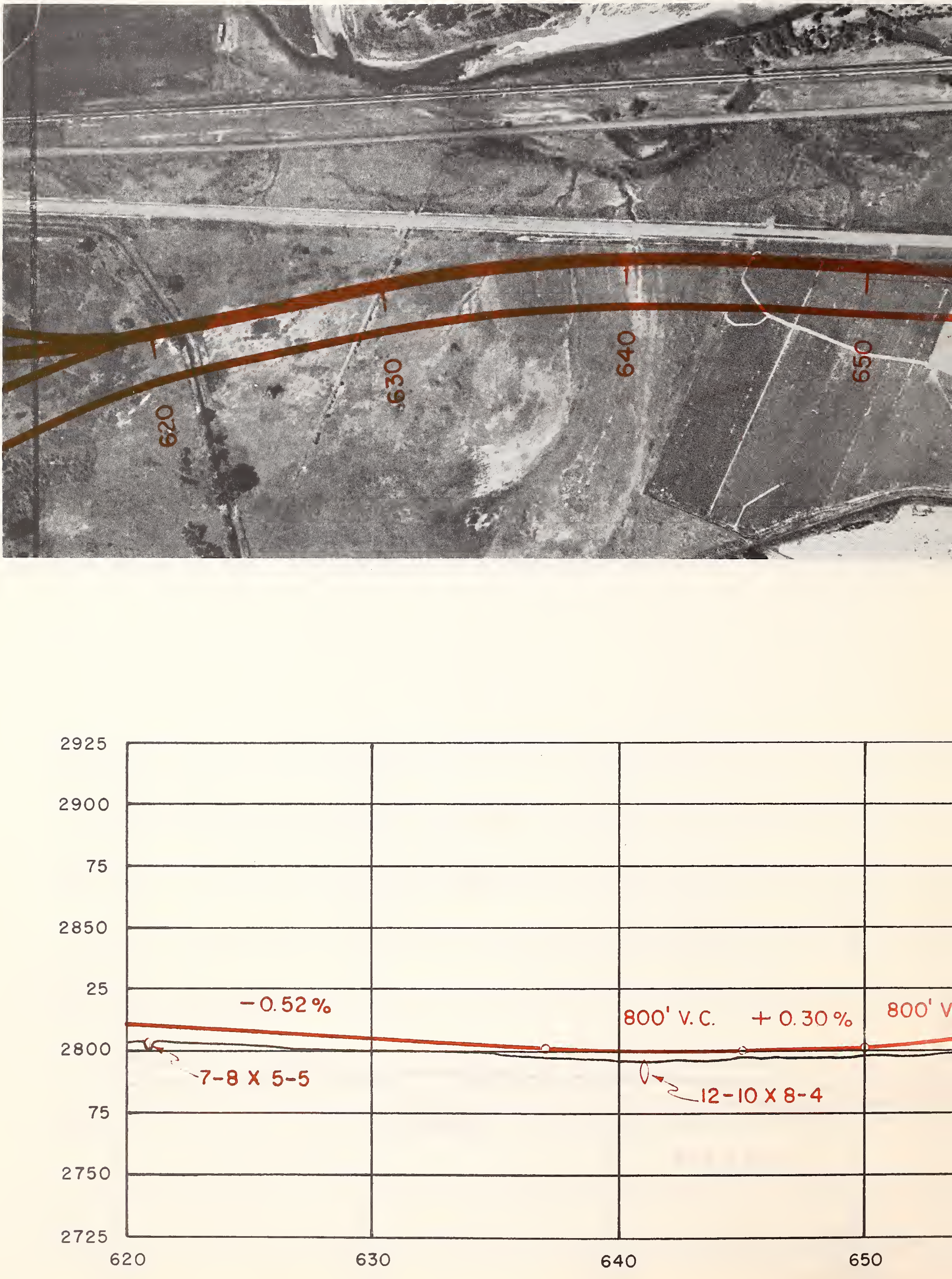
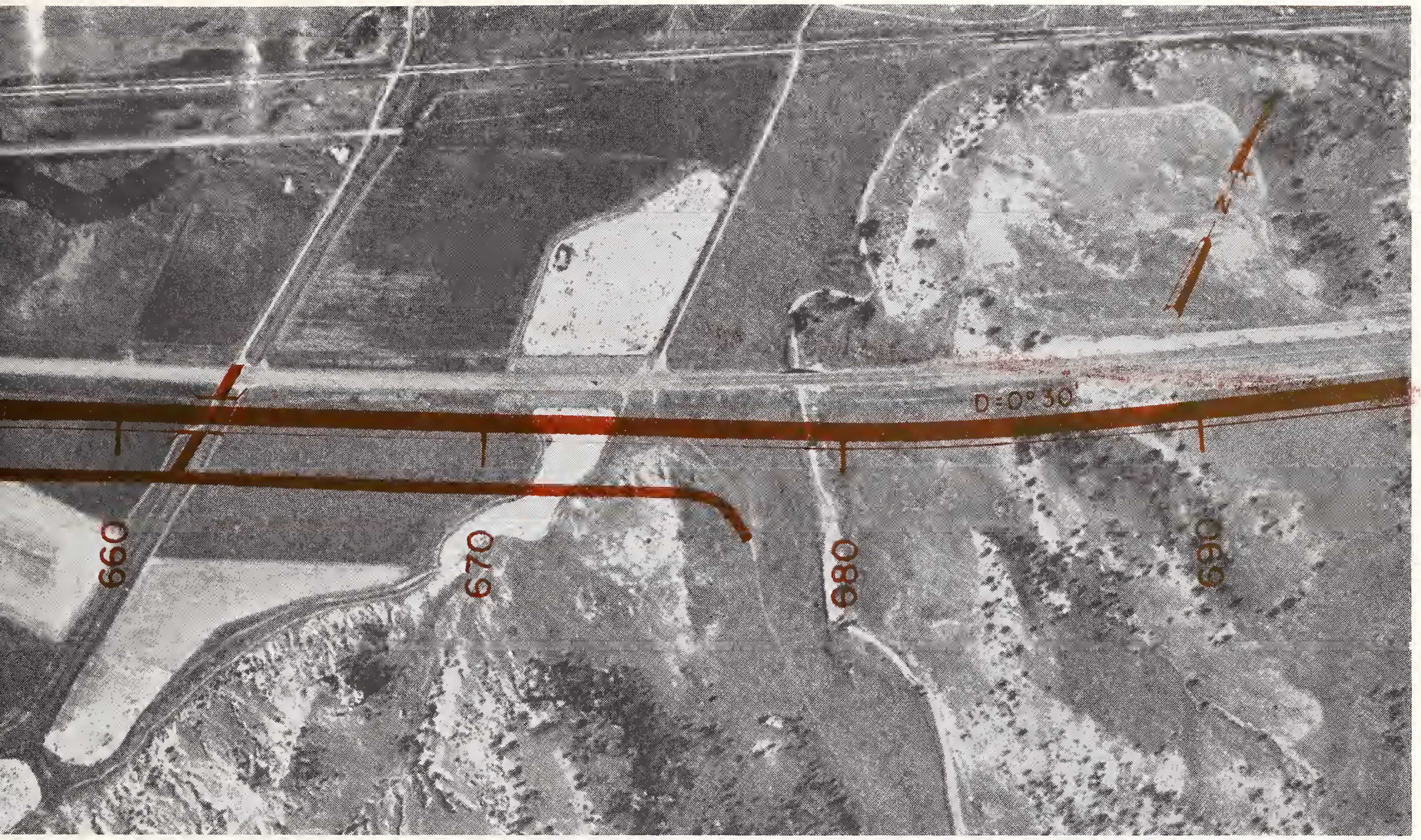

N
REST AREA
D=1°00'
590
600
610
620
2950
25
2900
75
2850
25
2800
75
2750
−0.52%
1600' V. C.
7-8 X 5-5
590
600
610
620

FIGURE 31


620
630
640
650
2925
2900
75
2850
25
2800
75
2750
2725
620
630
640
650
− 0.52 %
800' V. C.
+ 0.30 %
800' V
7-8 X 5-5
12-10 X 8-4


D=0°30'
660
670
680
690
N

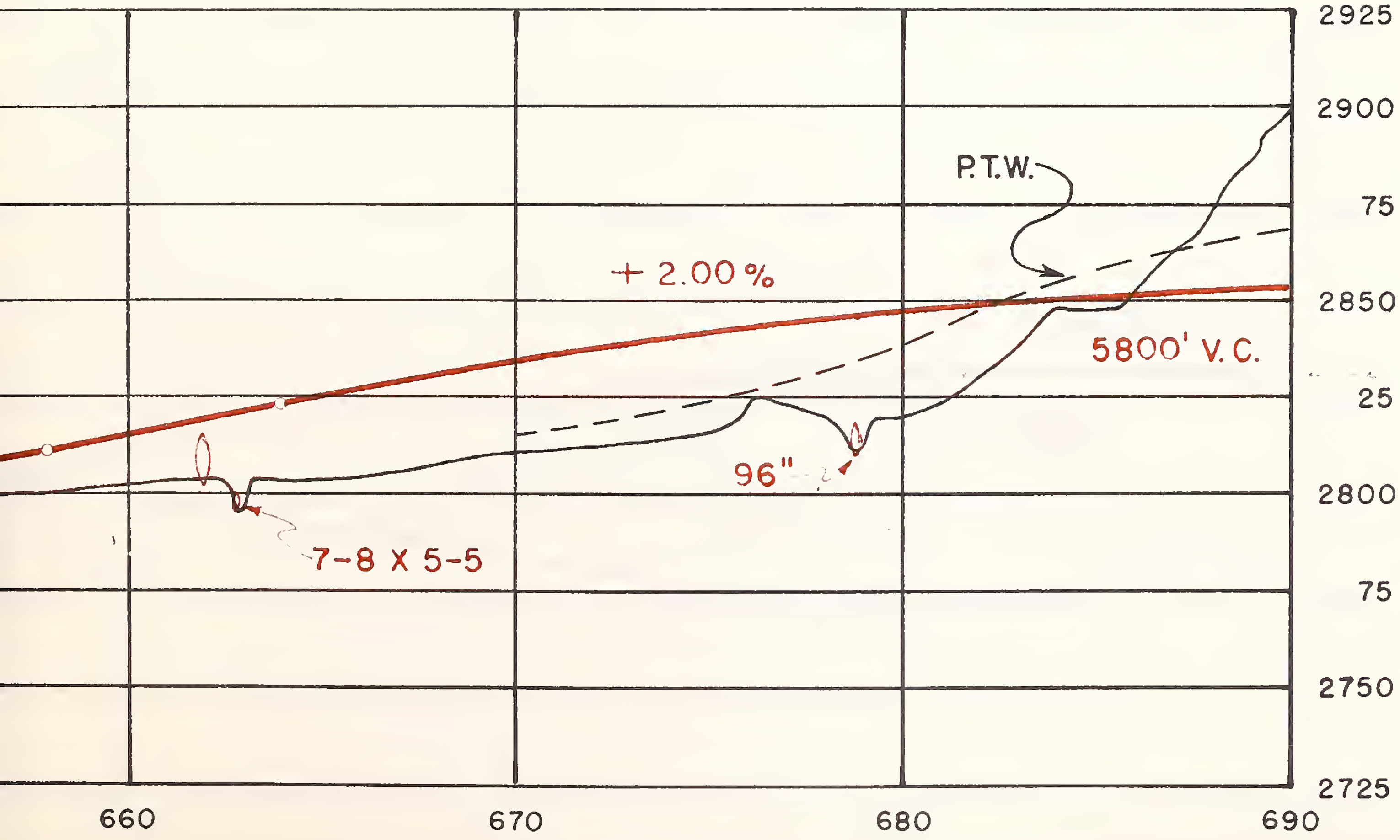

2925
2900
75
2850
25
2800
75
2750
2725
P.T.W.
+ 2.00 %
5800' V.C.
96"
7-8 X 5-5
660
670
680
690

FIGURE 33

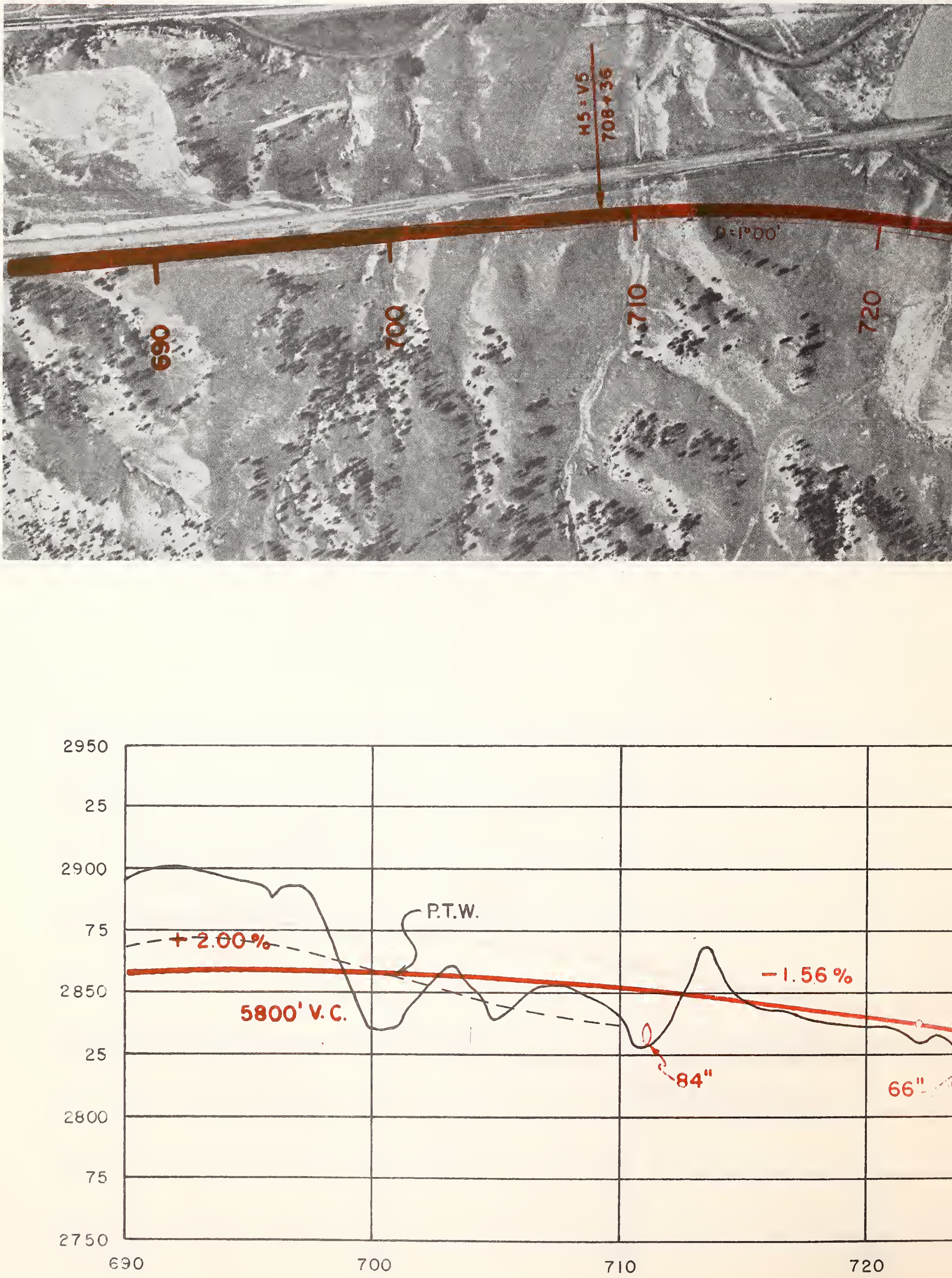

H5 = V5
708+36
D=1°00'
690
700
710
720
2950
25
2900
75
2850
25
2800
75
2750
P.T.W.
+2.00%
5800' V.C.
-1.56%
84"
66"
690
700
710
720

FIGURE 34

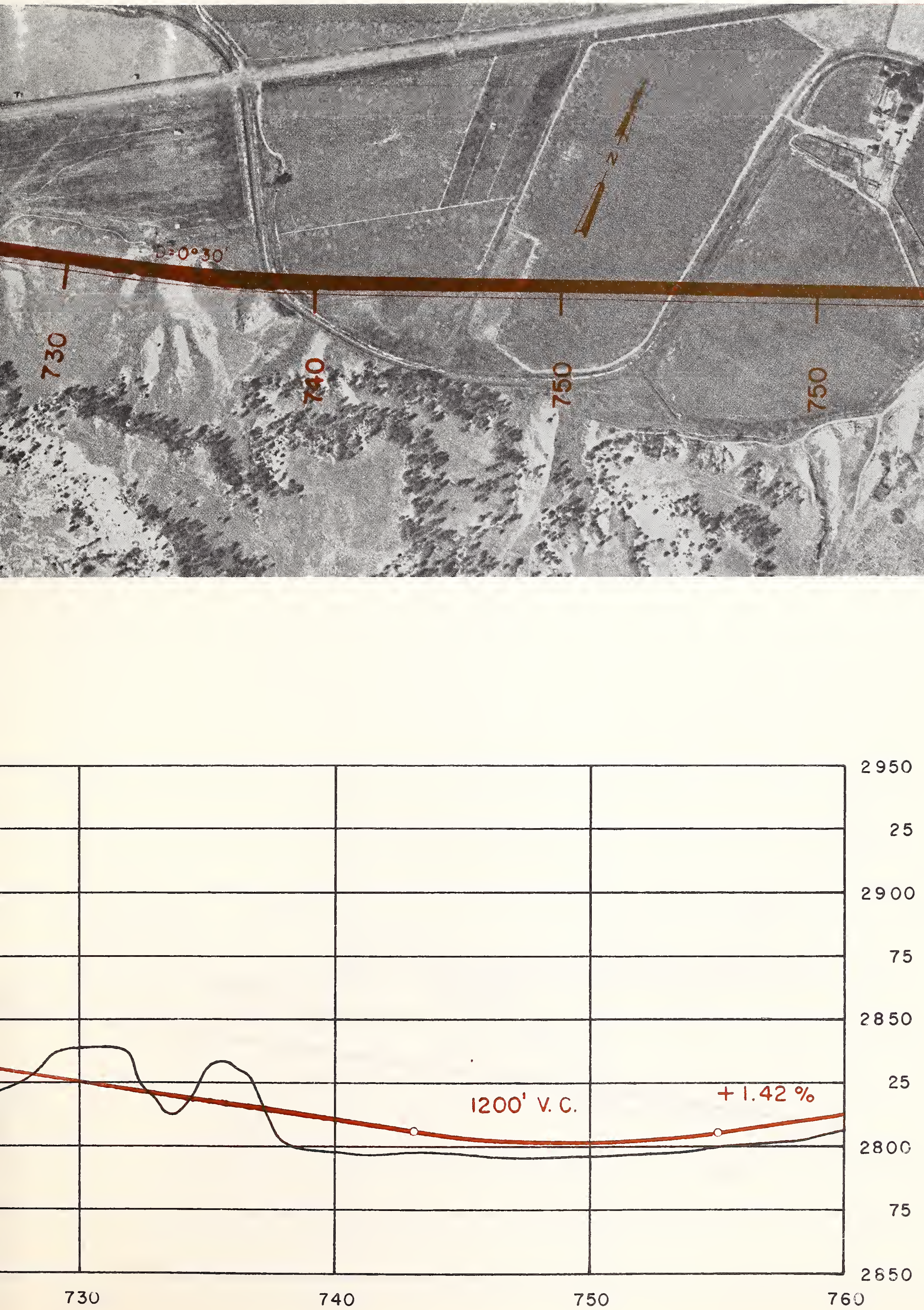

D=0°30'
N
730
740
750
750
2950
25
2900
75
2850
25
2800
75
2850
1200' V. C.
+ 1.42 %
730
740
750
760

FIGURE 35

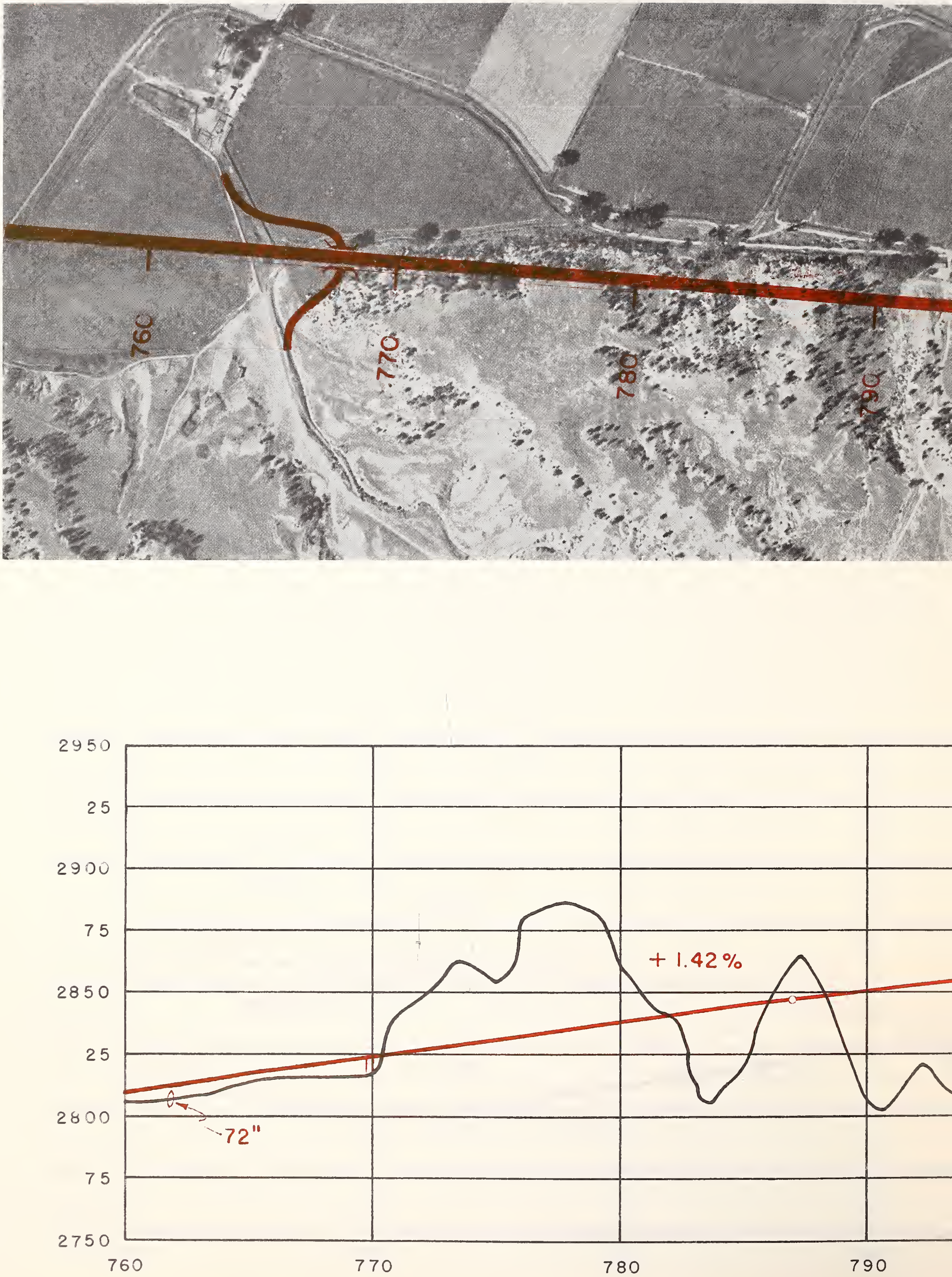
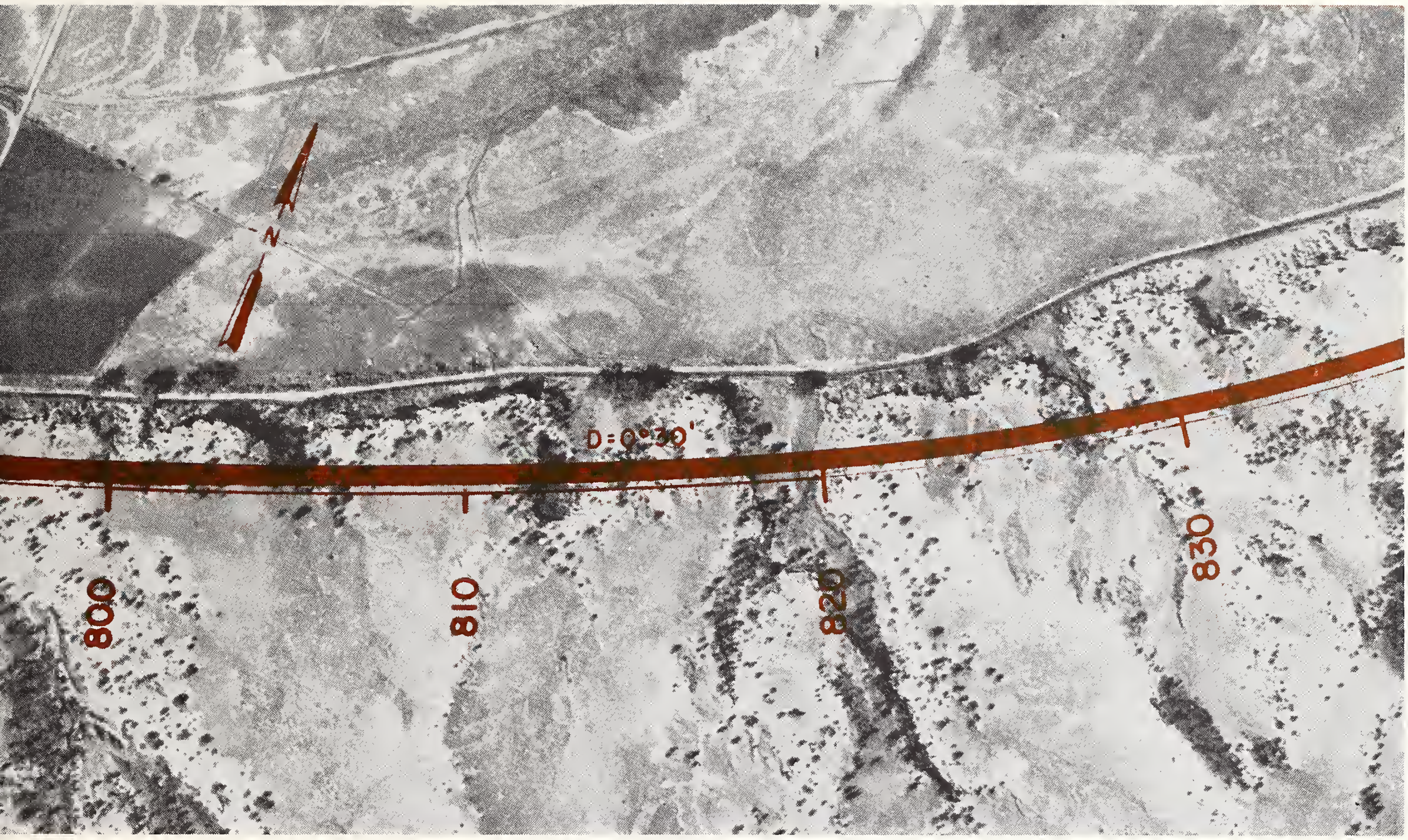

760
770
780
790
2950
25
2900
75
2850
25
2800
75
2750
760
770
780
790
+ 1.42 %
72"

FIGURE 36


N
D=0°30'
800
810
820
830

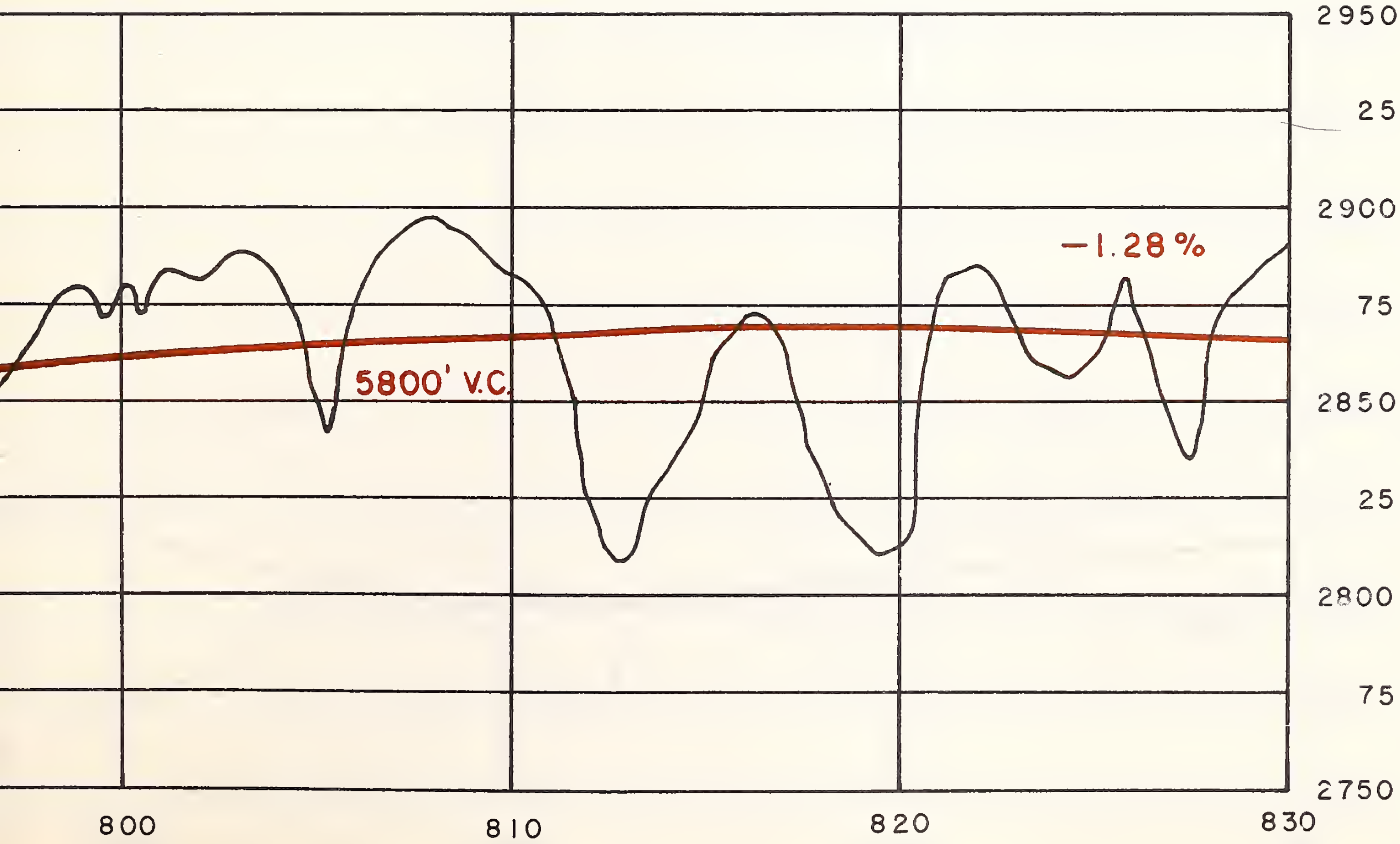
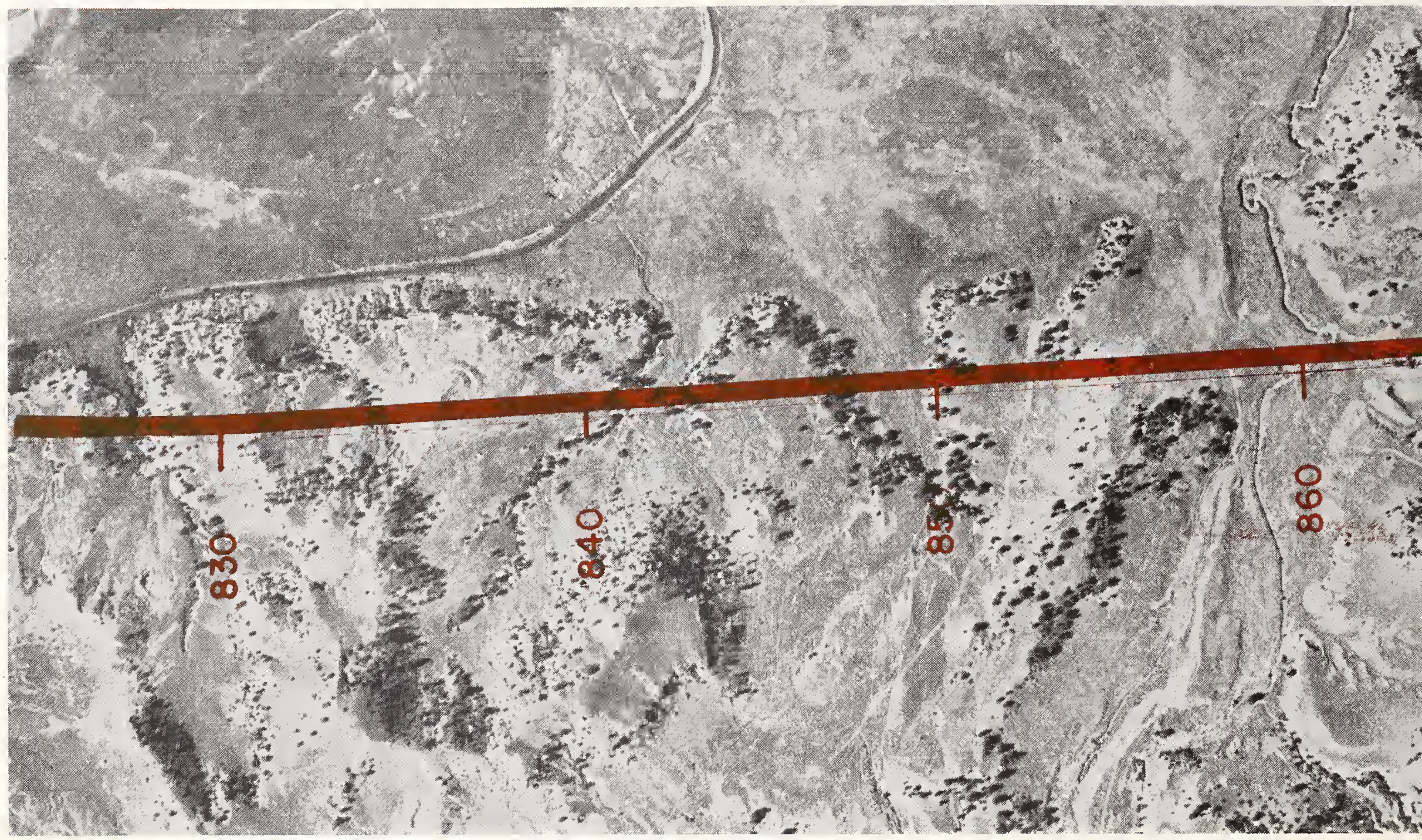
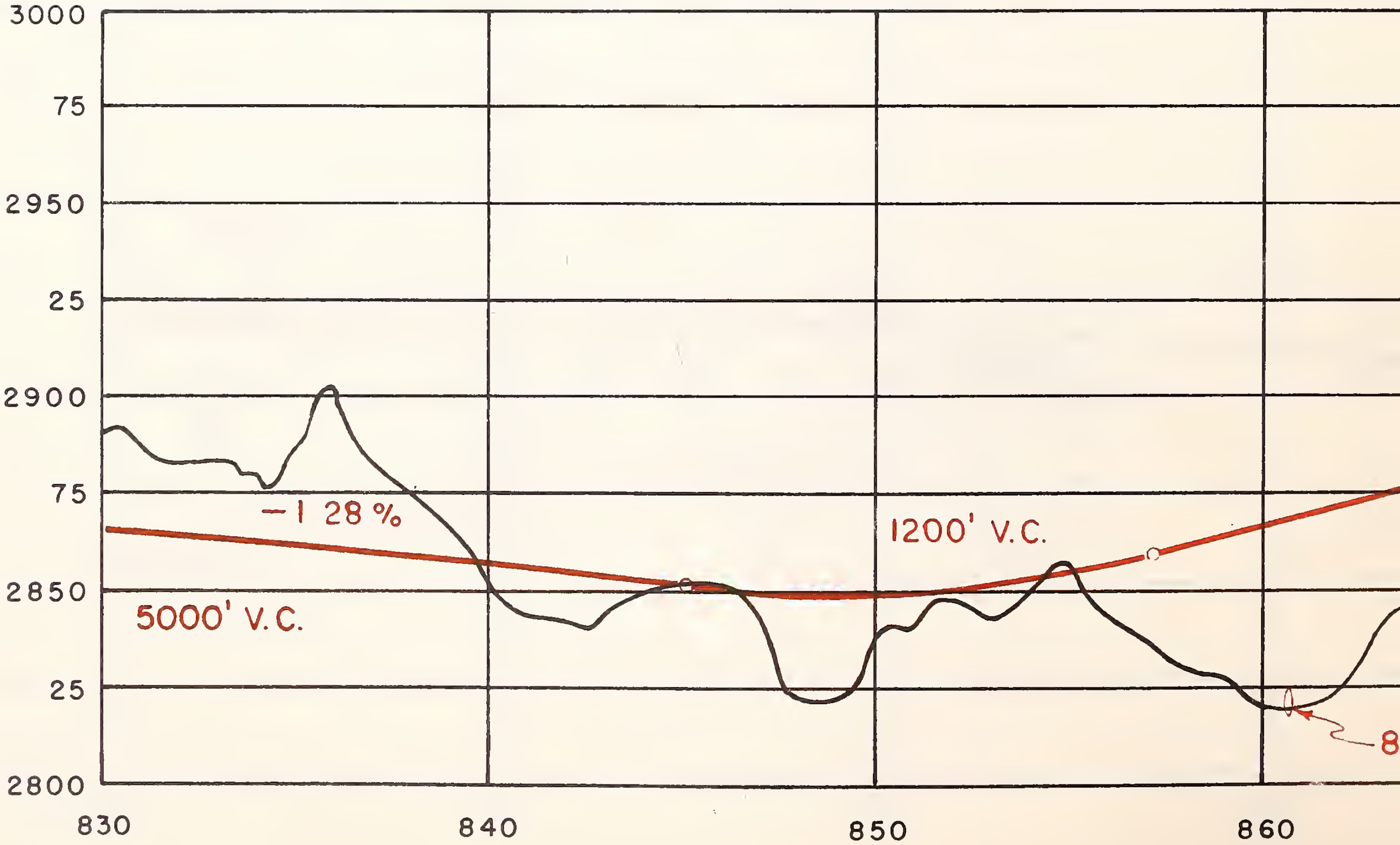

2950
25
2900
75
2850
25
2800
75
2750
−1.28 %
5800' V.C.
800
810
820
830

FIGURE 37



830
840
850
860



3000
75
2950
25
2900
75
2850
25
2800
830
840
850
860
−1 28 %
1200' V.C.
5000' V.C.
8

FIGURE 38

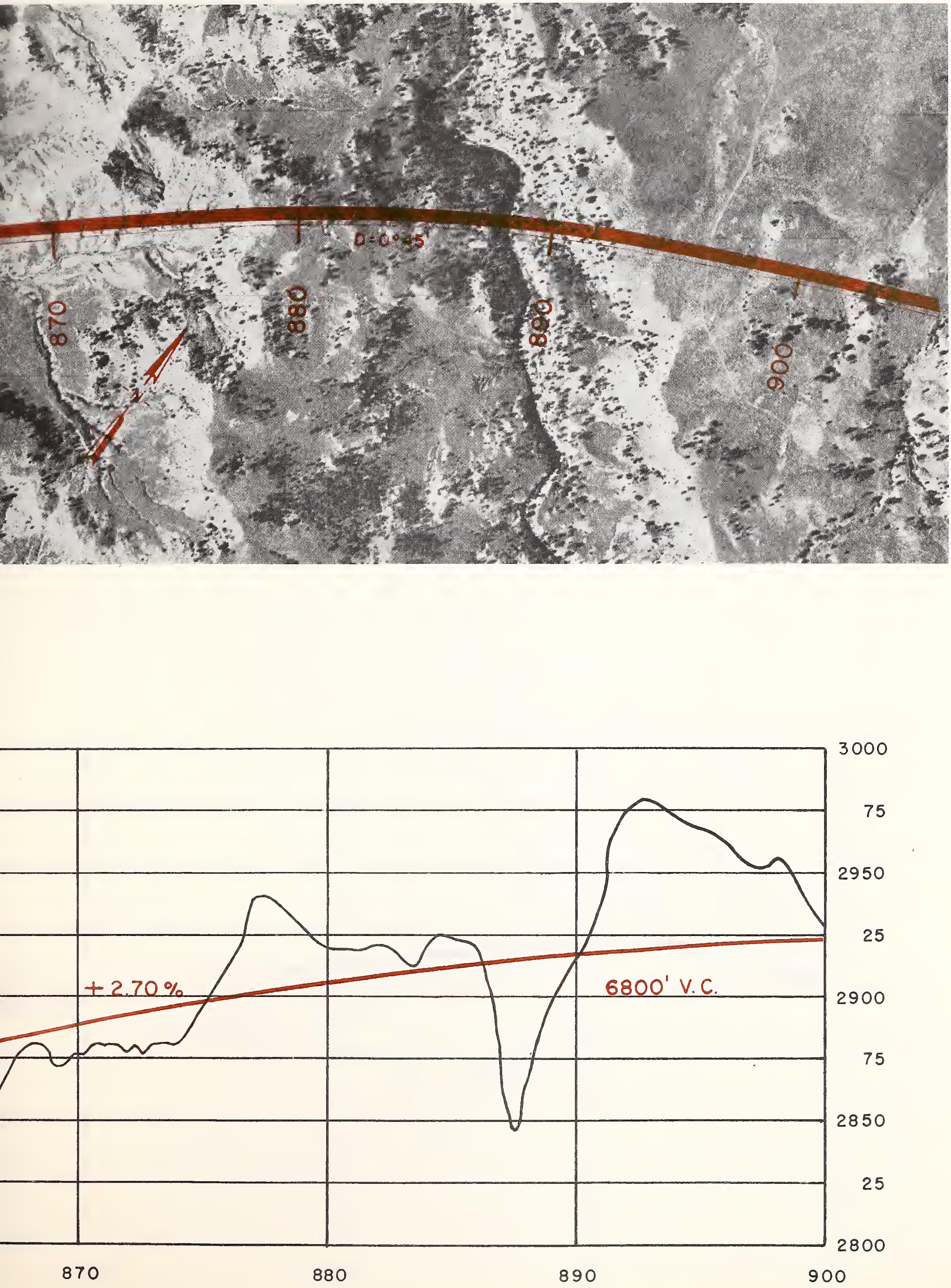
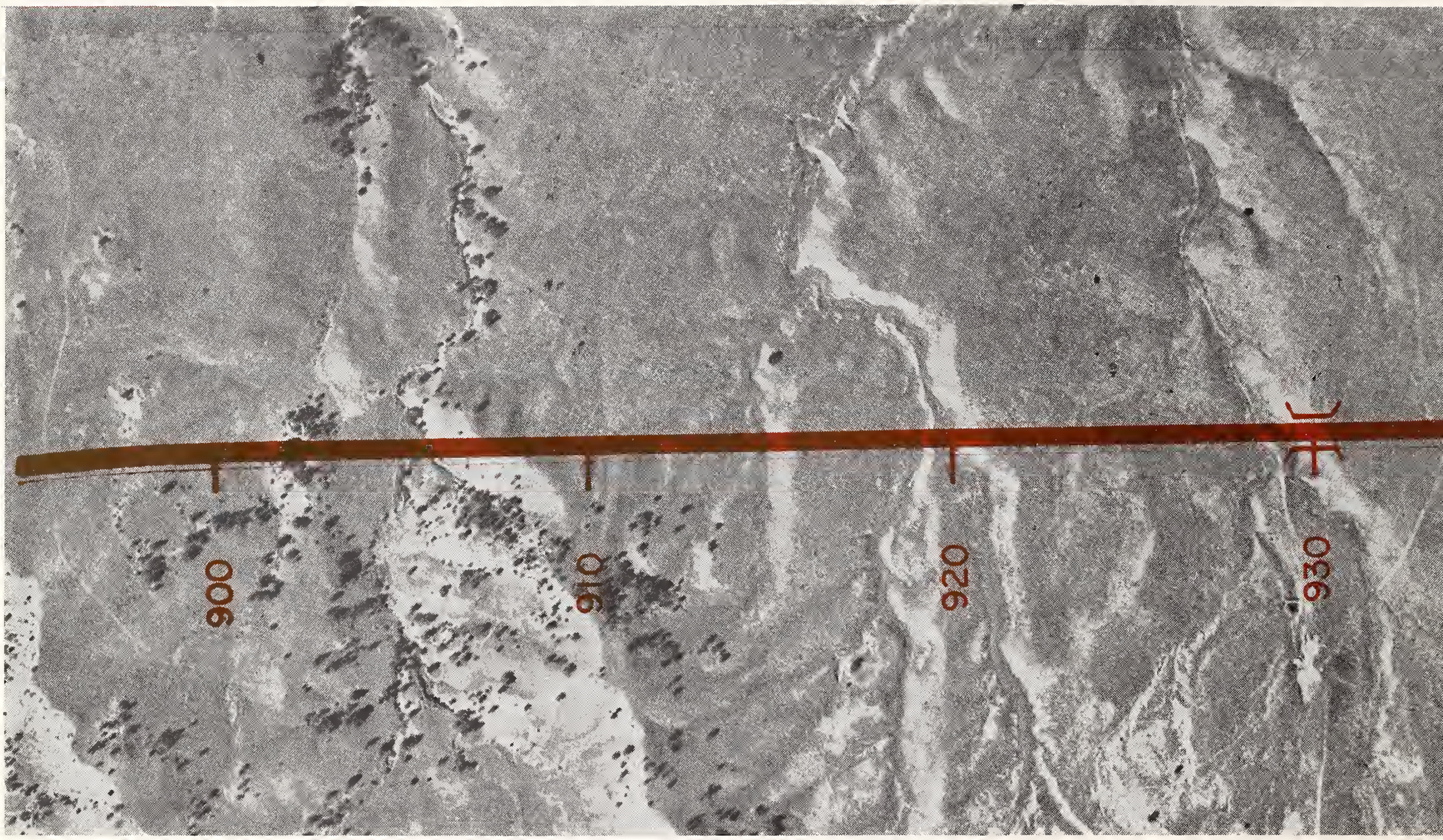

D=0°45'
870
880
890
900
3000
75
2950
25
2900
75
2850
25
2800
+2.70%
6800' V.C.
870
880
890
900

FIGURE 39


900
910
920
930

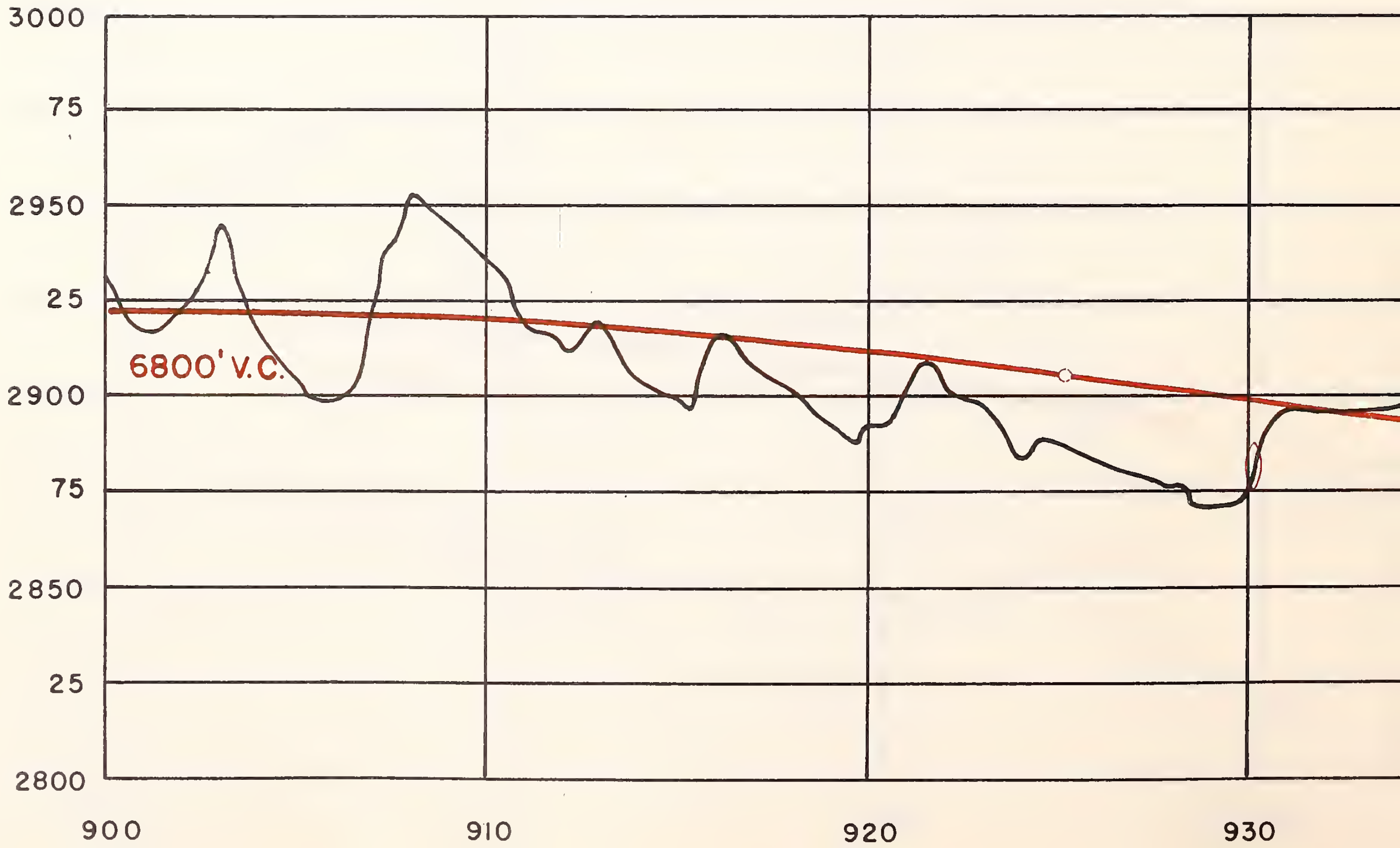

3000
75
2950
25
2900
75
2850
25
2800
6800' V.C.
900
910
920
930

FIGURE 40

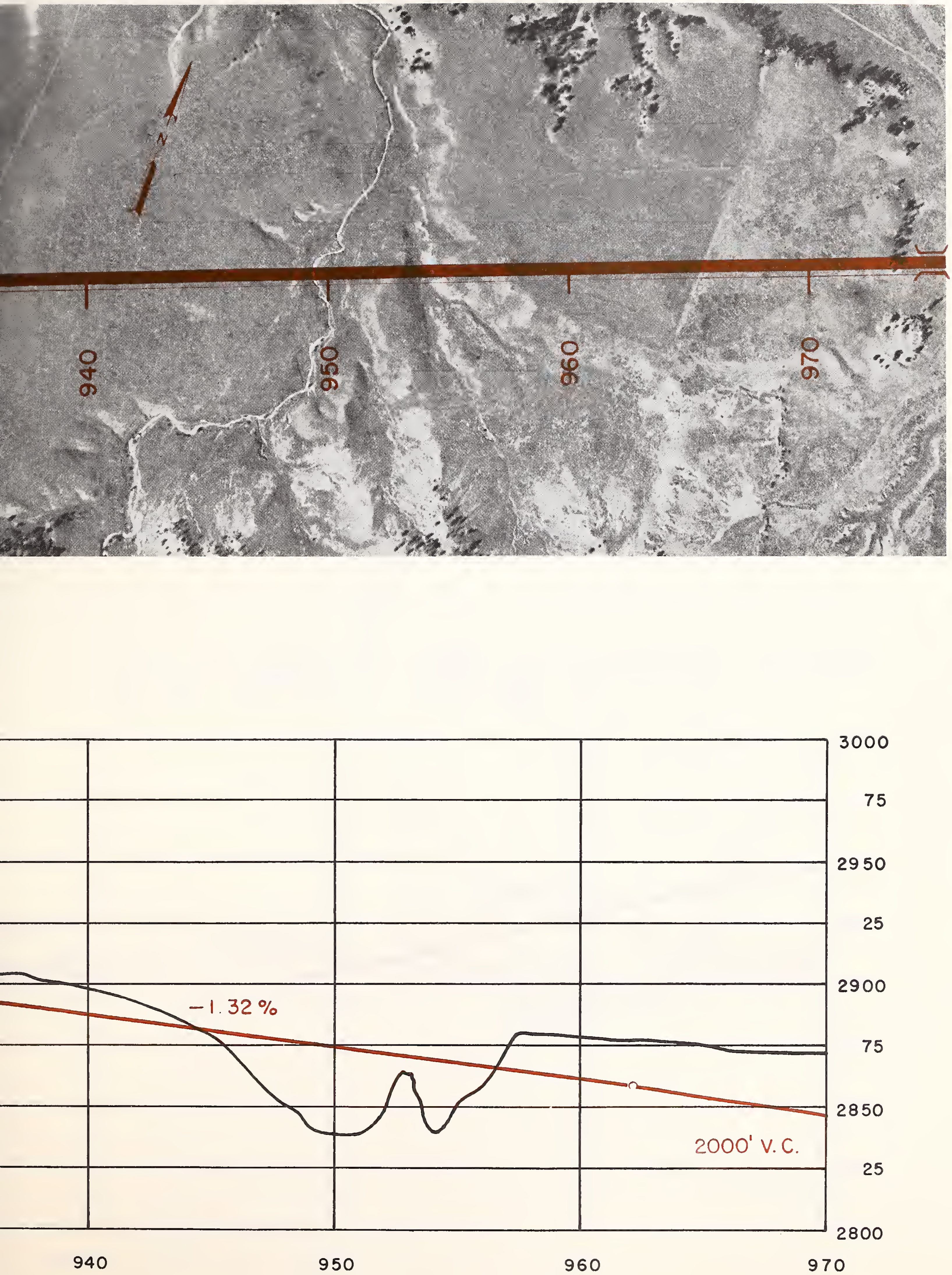

N
940
950
960
970
3000
75
2950
25
2900
75
2850
25
2800
−1.32 %
2000' V. C.
940
950
960
970

FIGURE 41

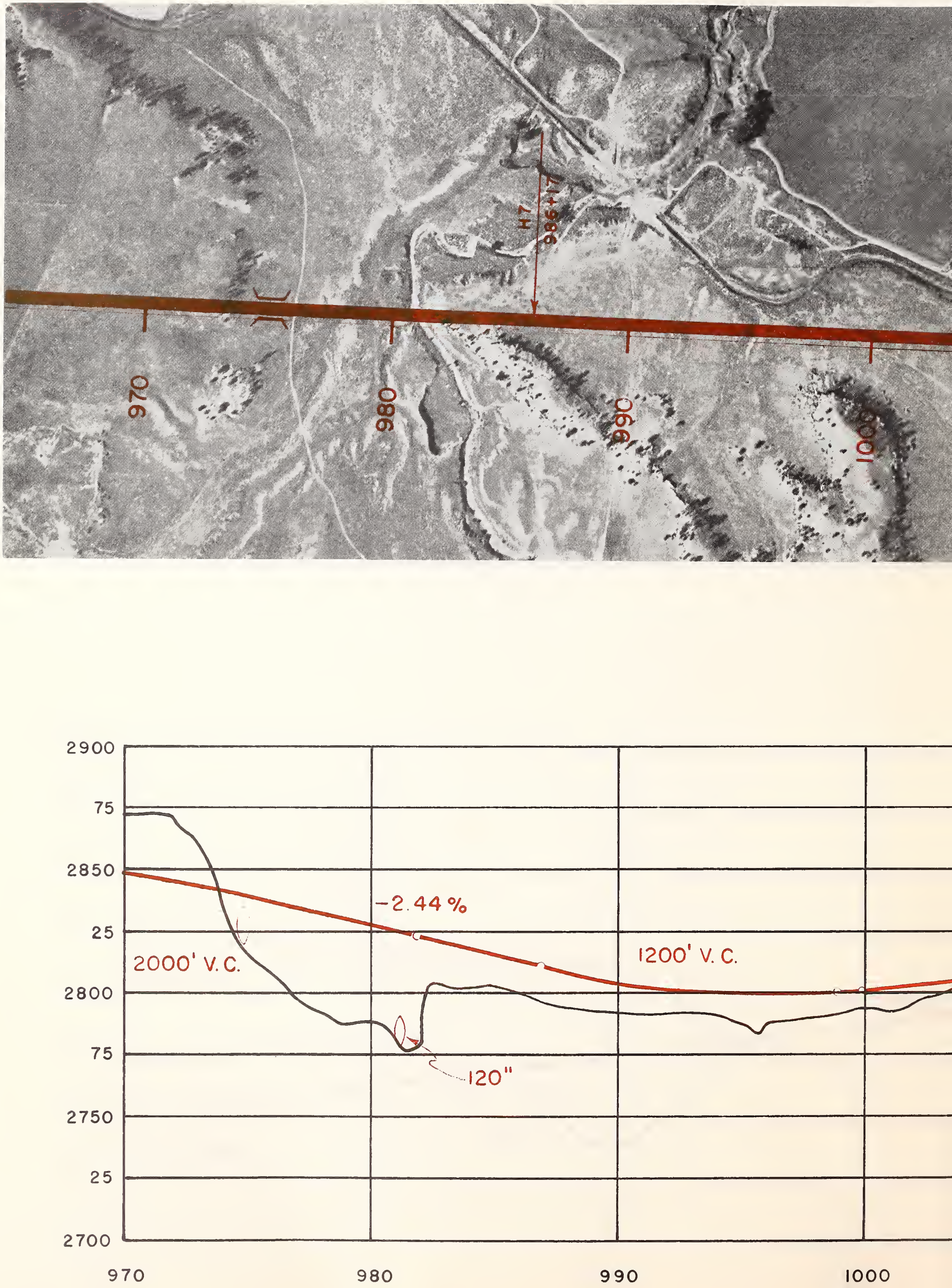
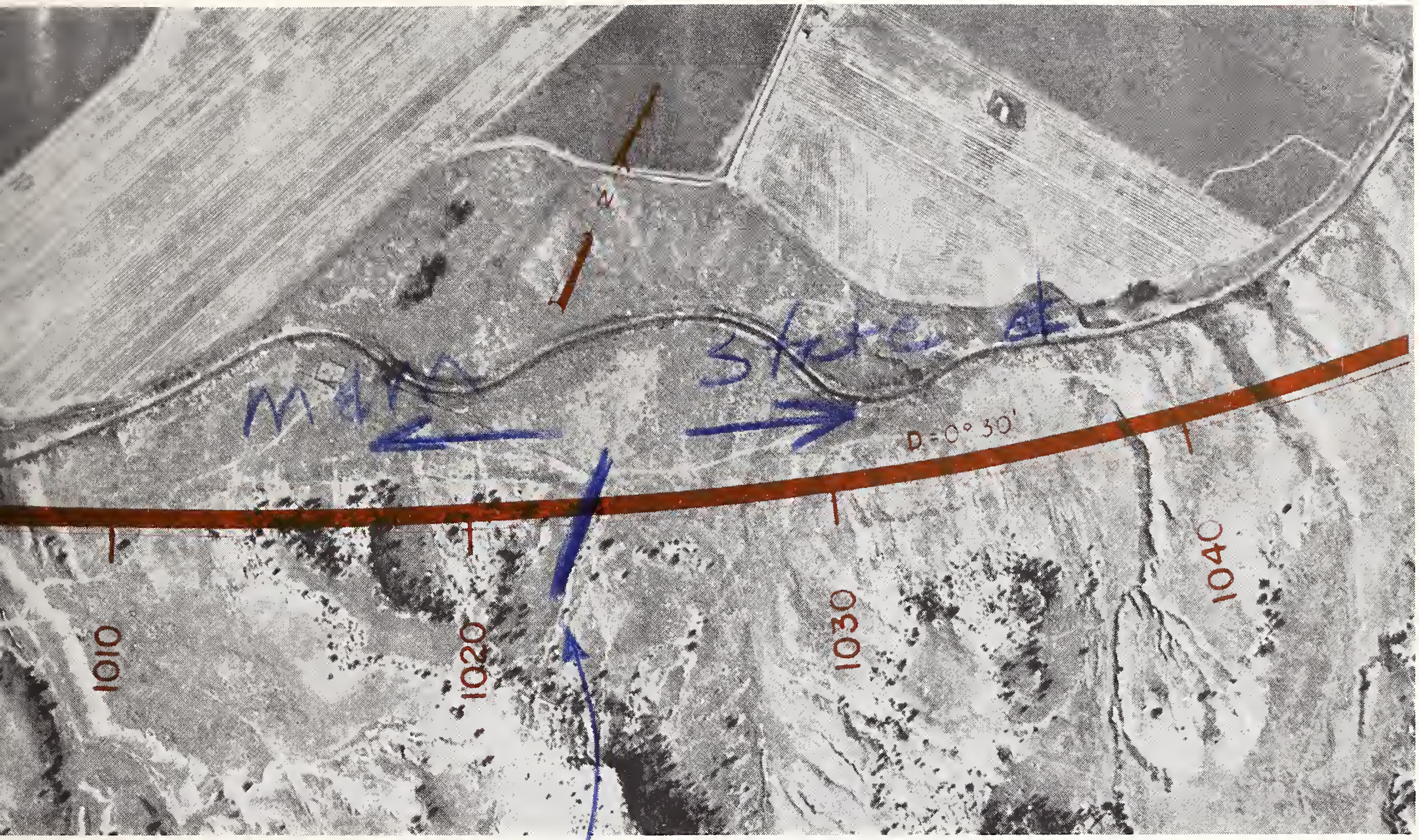

H7
986+17
970
980
990
1000
2900
75
2850
25
2800
75
2750
25
2700
-2.44 %
2000' V. C.
1200' V. C.
120"
970
980
990
1000

FIGURE 42



End design at aprox sta 1023±

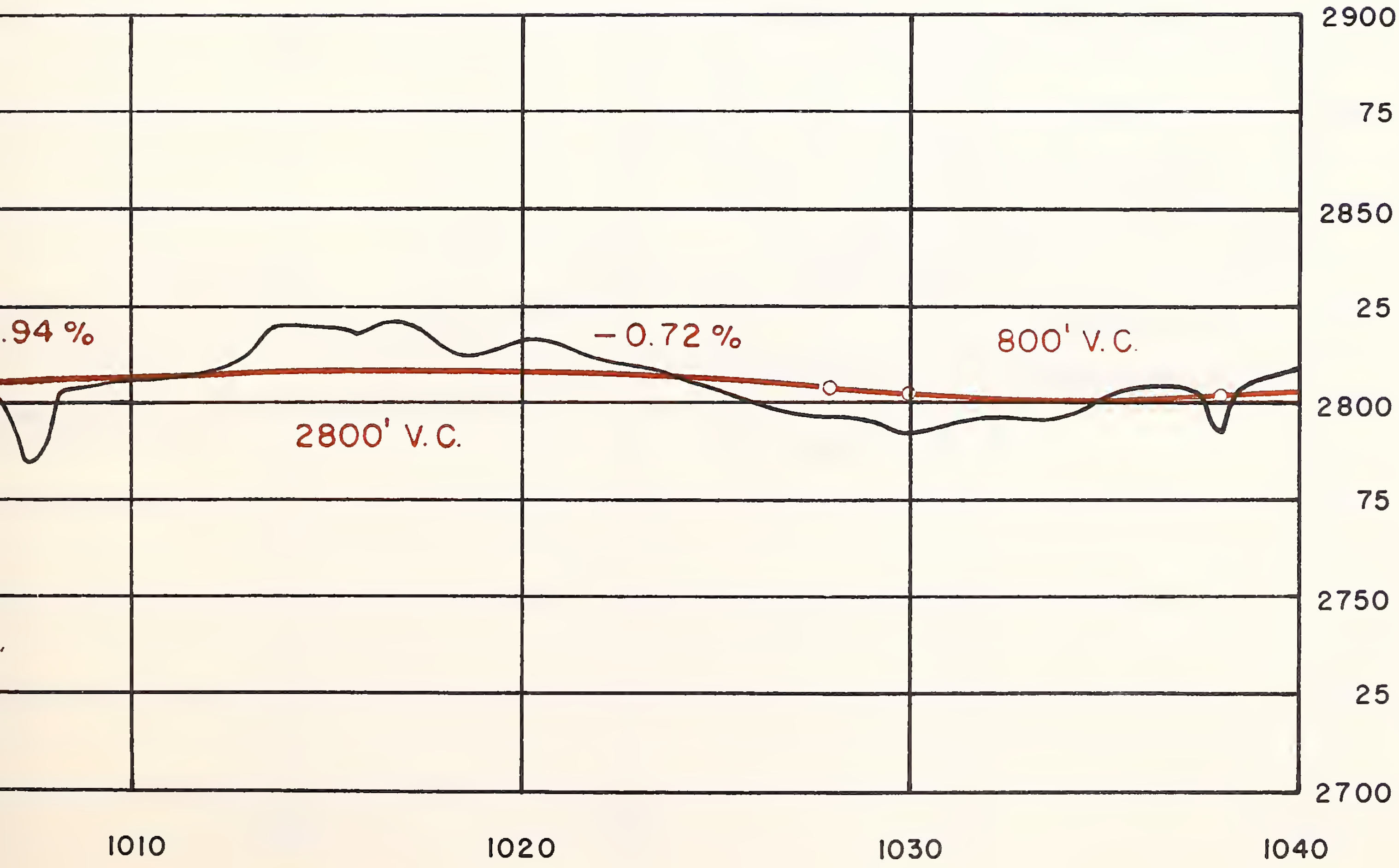


FIGURE 43

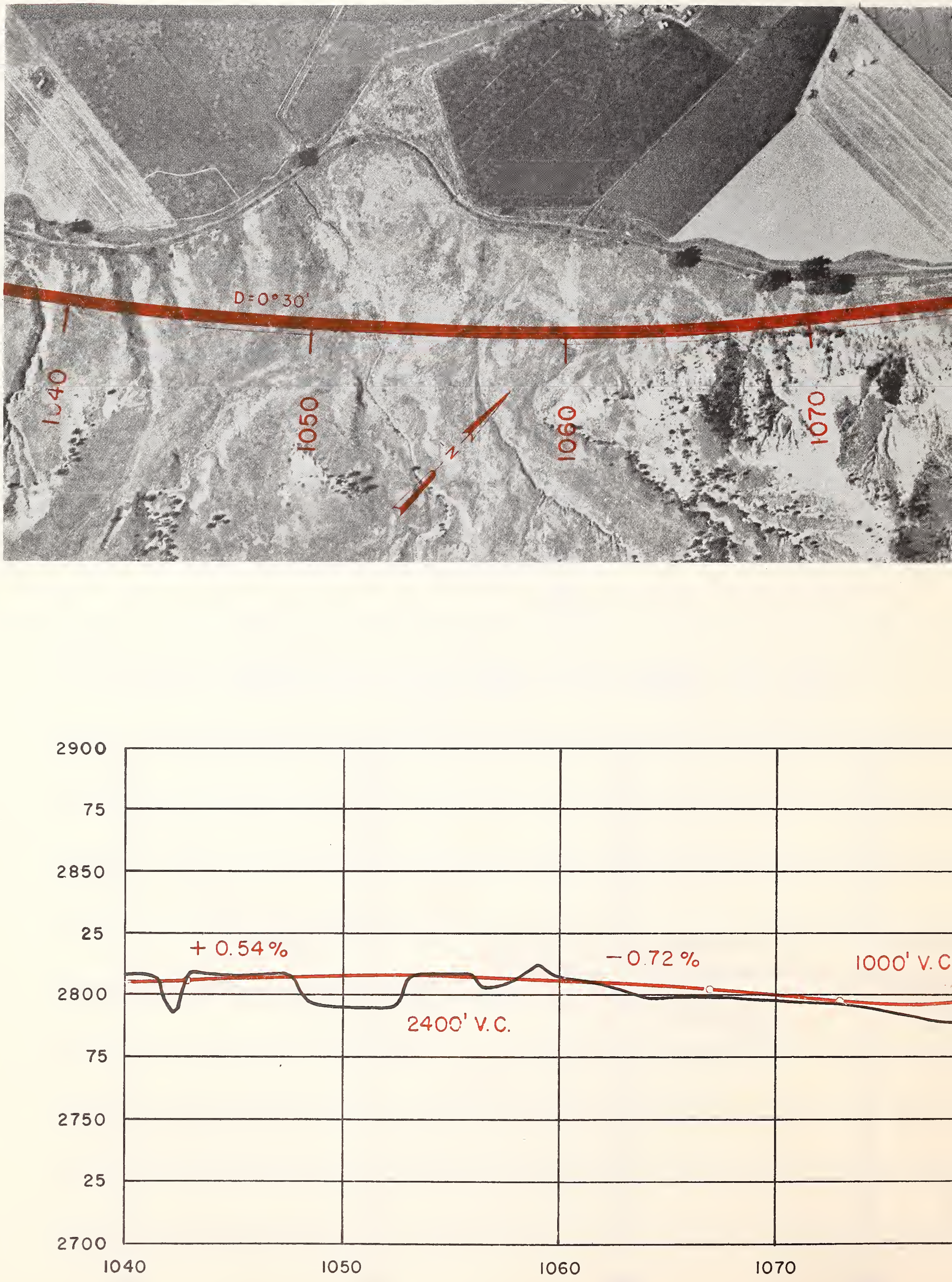

D=0°30'
1040
1050
1060
1070
N
2900
75
2850
25
2800
75
2750
25
2700
+ 0.54 %
− 0.72 %
2400' V.C.
1000' V.C
1040
1050
1060
1070

FIGURE 44

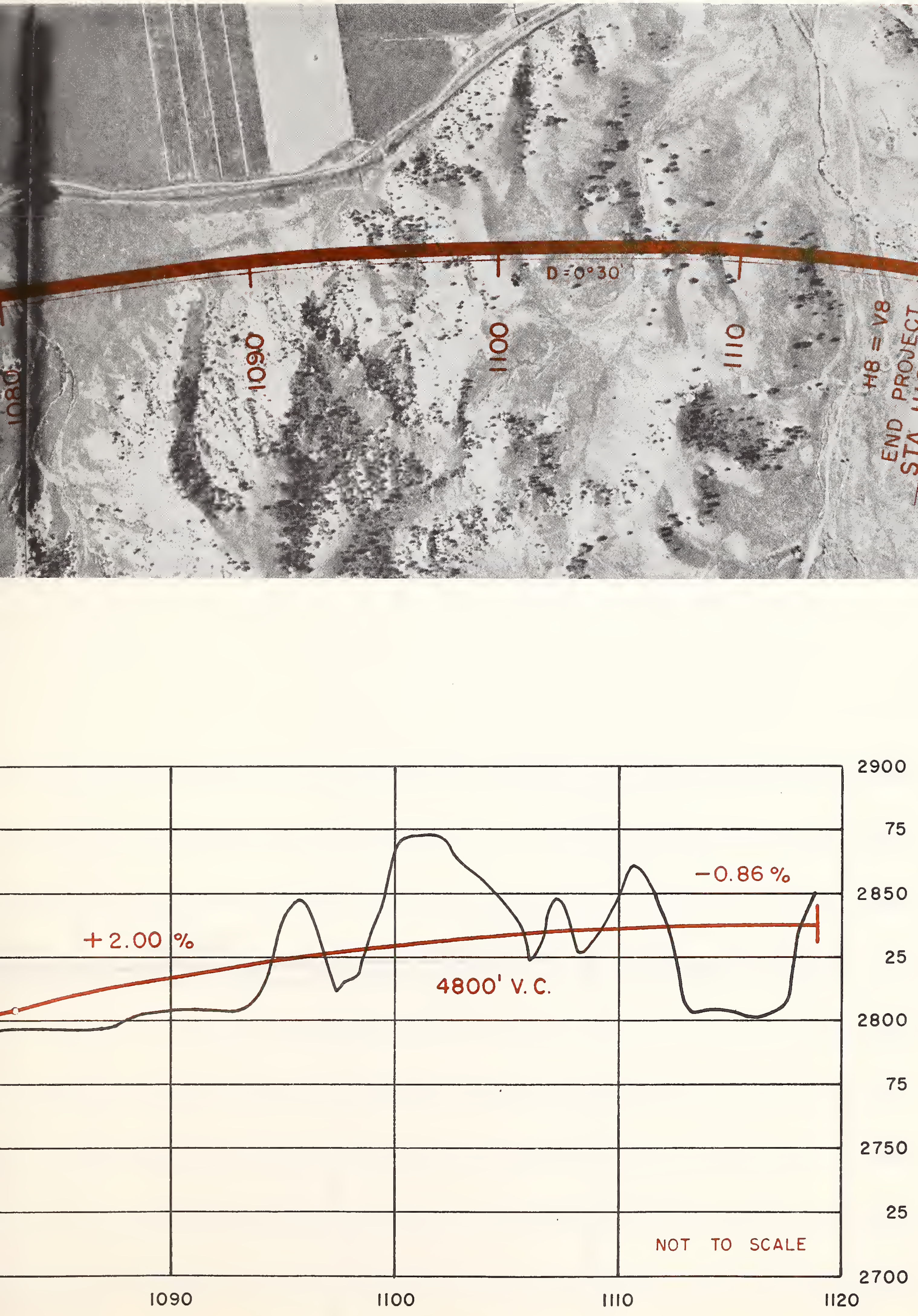

D = 0°30'
1080
1090
1100
1110
H8 = V8
END PROJECT
STA. 1118+49
+ 2.00 %
4800' V. C.
− 0.86 %
NOT TO SCALE
2900
75
2850
25
2800
75
2750
25
2700
1090
1100
1110
1120

FIGURE 45

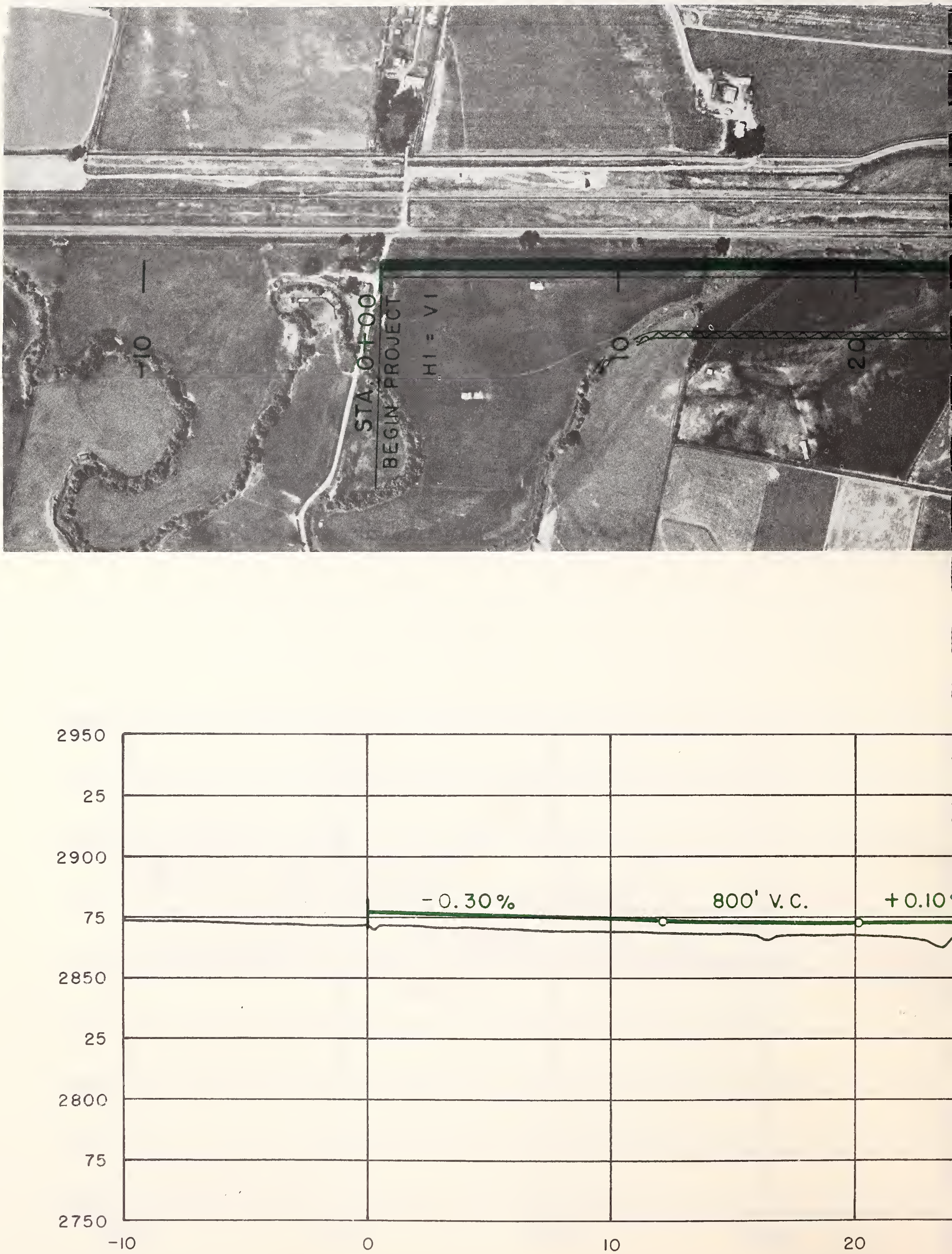

-10
STA. 0+00
BEGIN PROJECT
H1 = V1
10
20
2950
25
2900
75
2850
25
2800
75
2750
-10
0
10
20
-0.30%
800' V. C.
+0.10

FIGURE 46

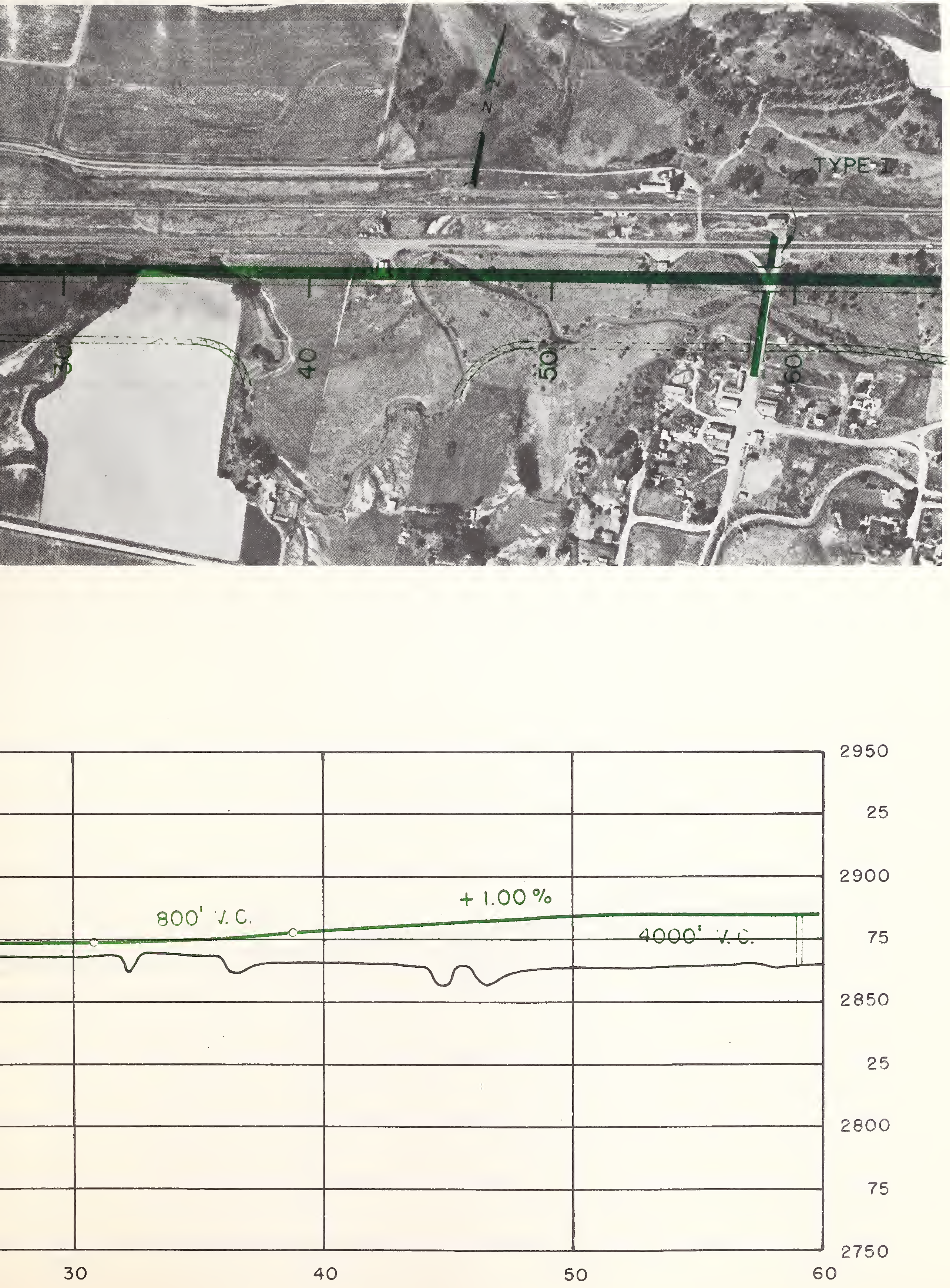
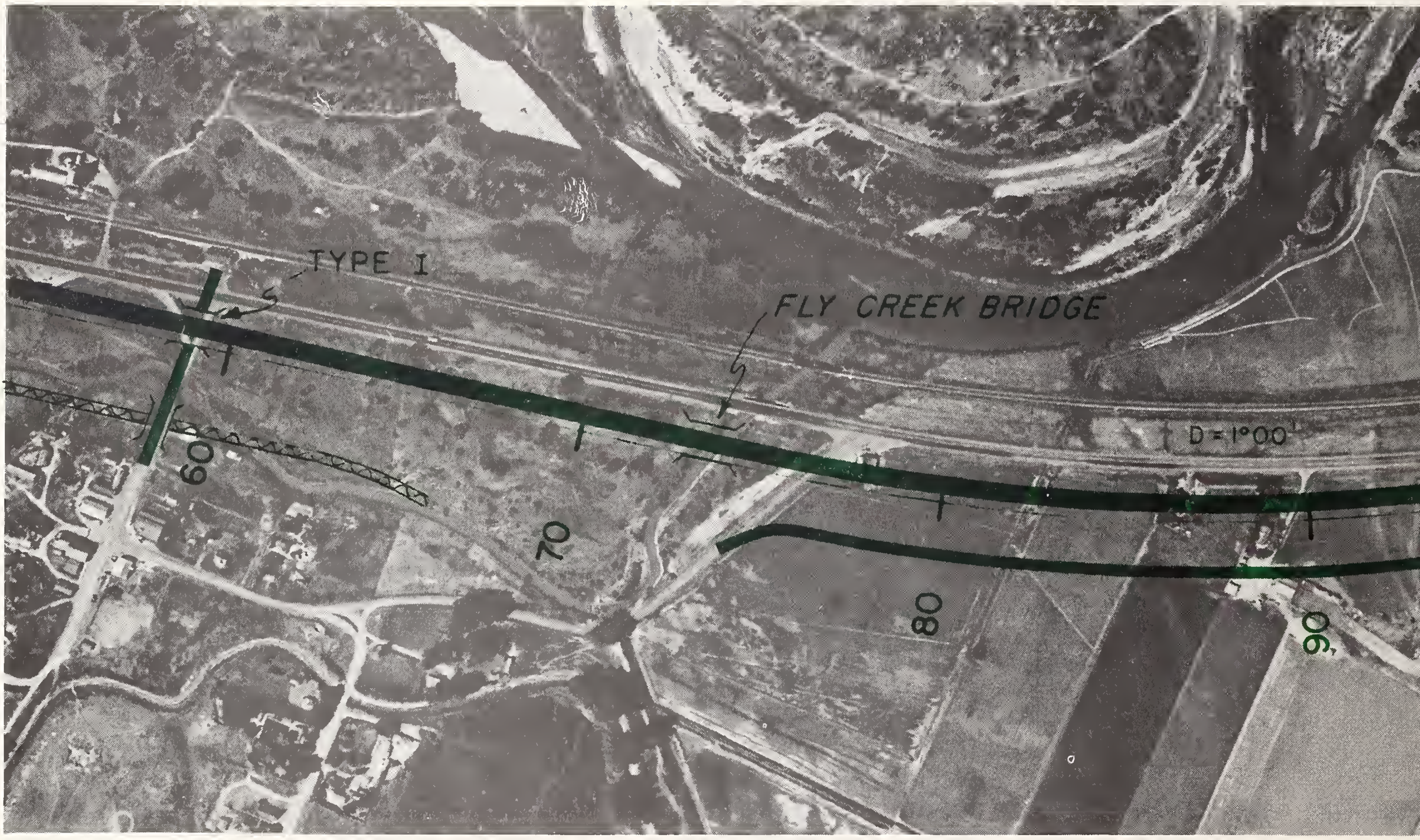

N
TYPE I
30
40
50
60
2950
25
2900
75
2850
25
2800
75
2750
800' V.C.
+ 1.00 %
4000' V.C.
30
40
50
60

FIGURE 47


TYPE I
FLY CREEK BRIDGE
D=1°00'
60
70
80
90

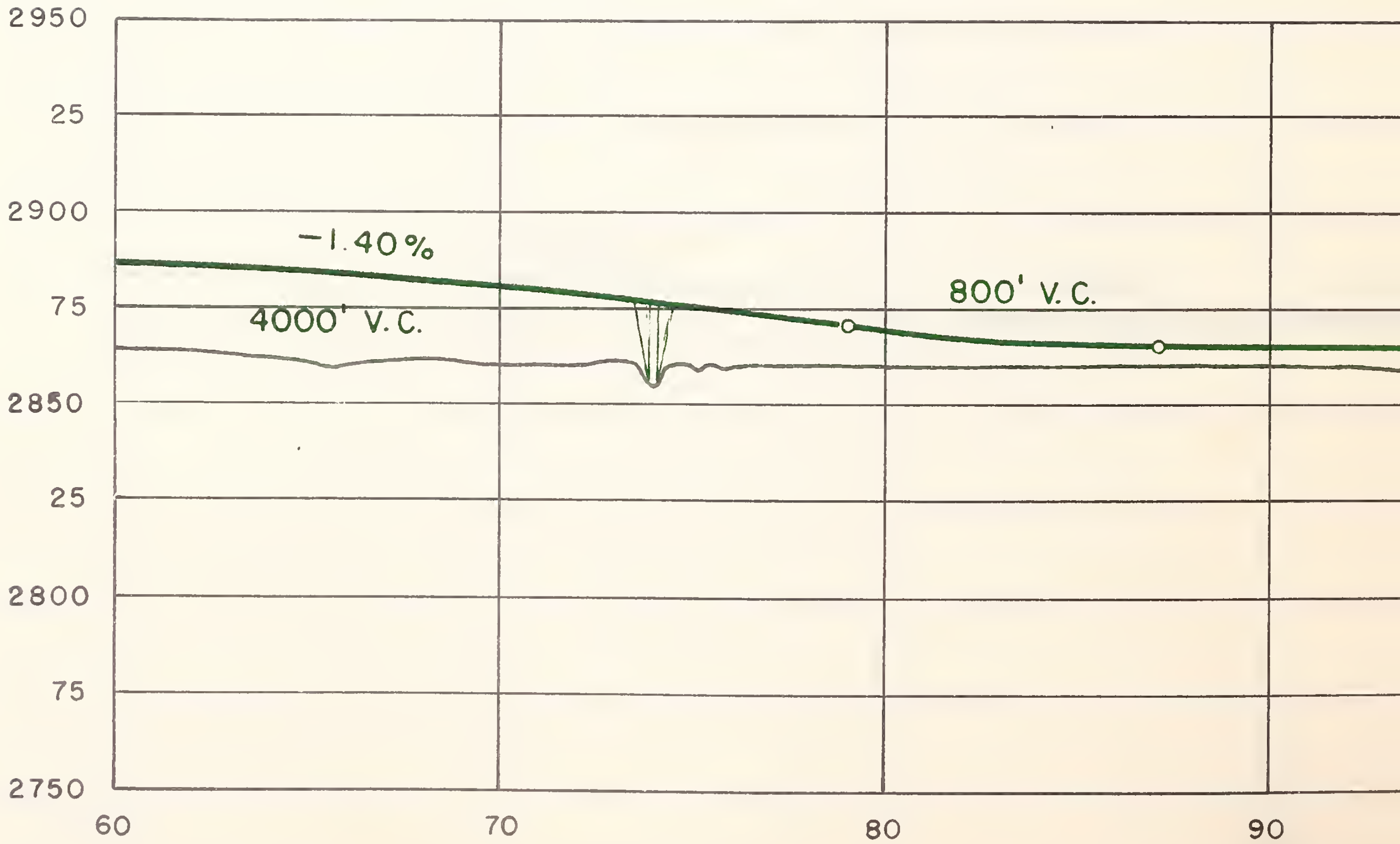

2950
25
2900
75
2850
25
2800
75
2750
60
70
80
90
−1.40%
4000' V.C.
800' V.C.

FIGURE 48

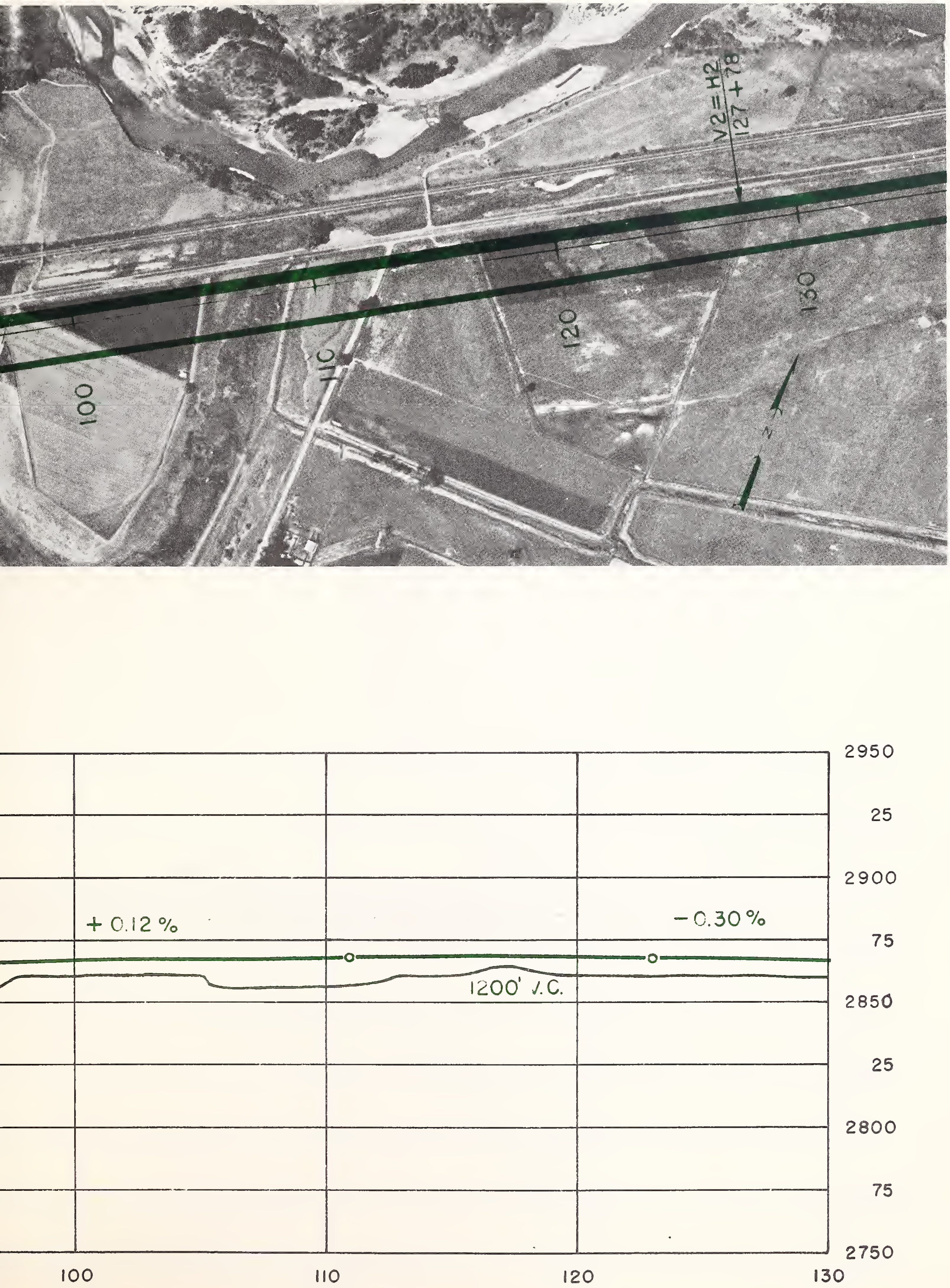
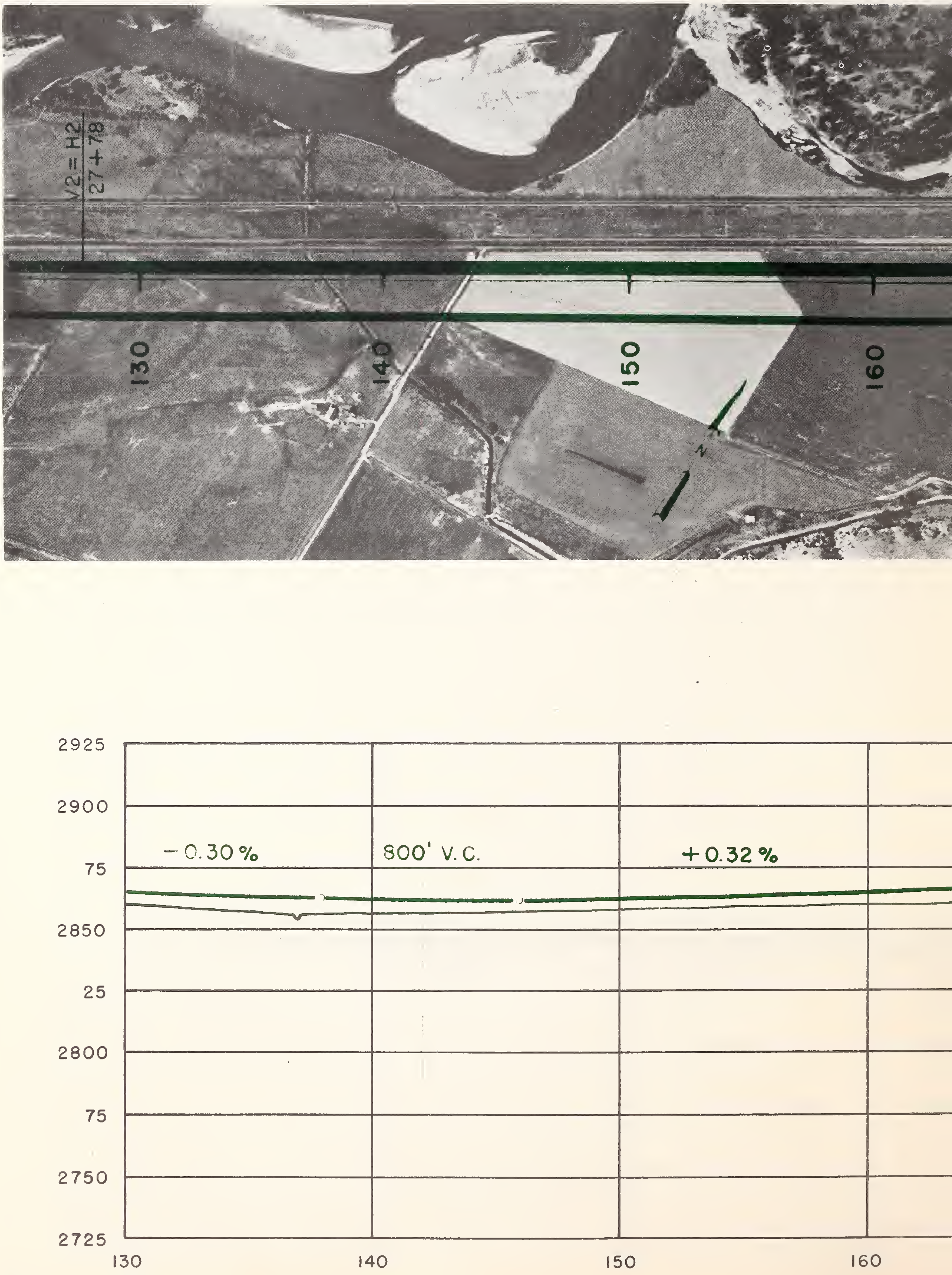
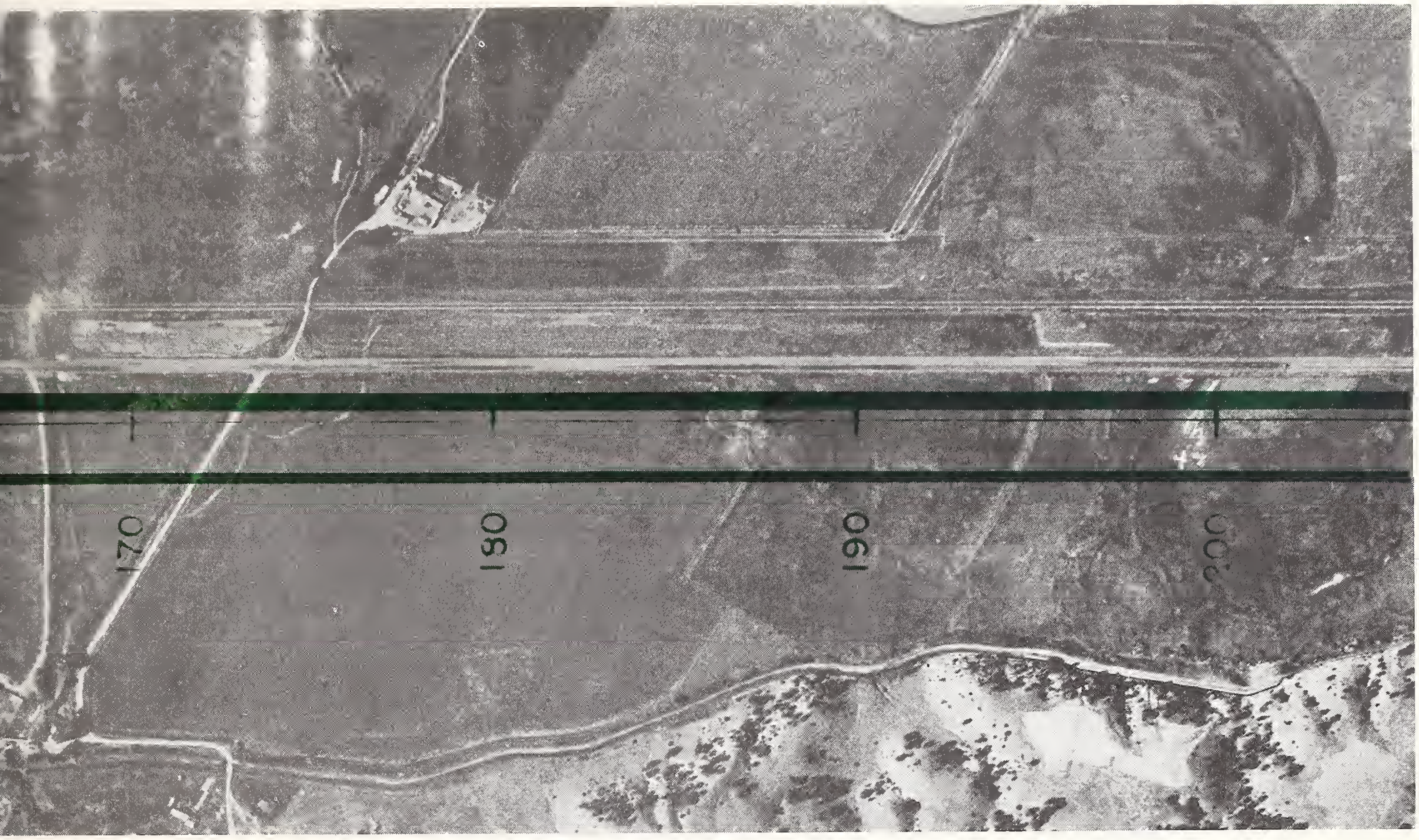

V2 = H2
127 + 78
100
110
120
130
N
+ 0.12 %
− 0.30 %
1200' V.C.
2950
25
2900
75
2850
25
2800
75
2750
100
110
120
130

FIGURE 49


V2 = H2
127+78
130
140
150
160
N
2925
2900
75
2850
25
2800
75
2750
2725
− 0.30 %
800' V.C.
+ 0.32 %
130
140
150
160


170
180
190
200

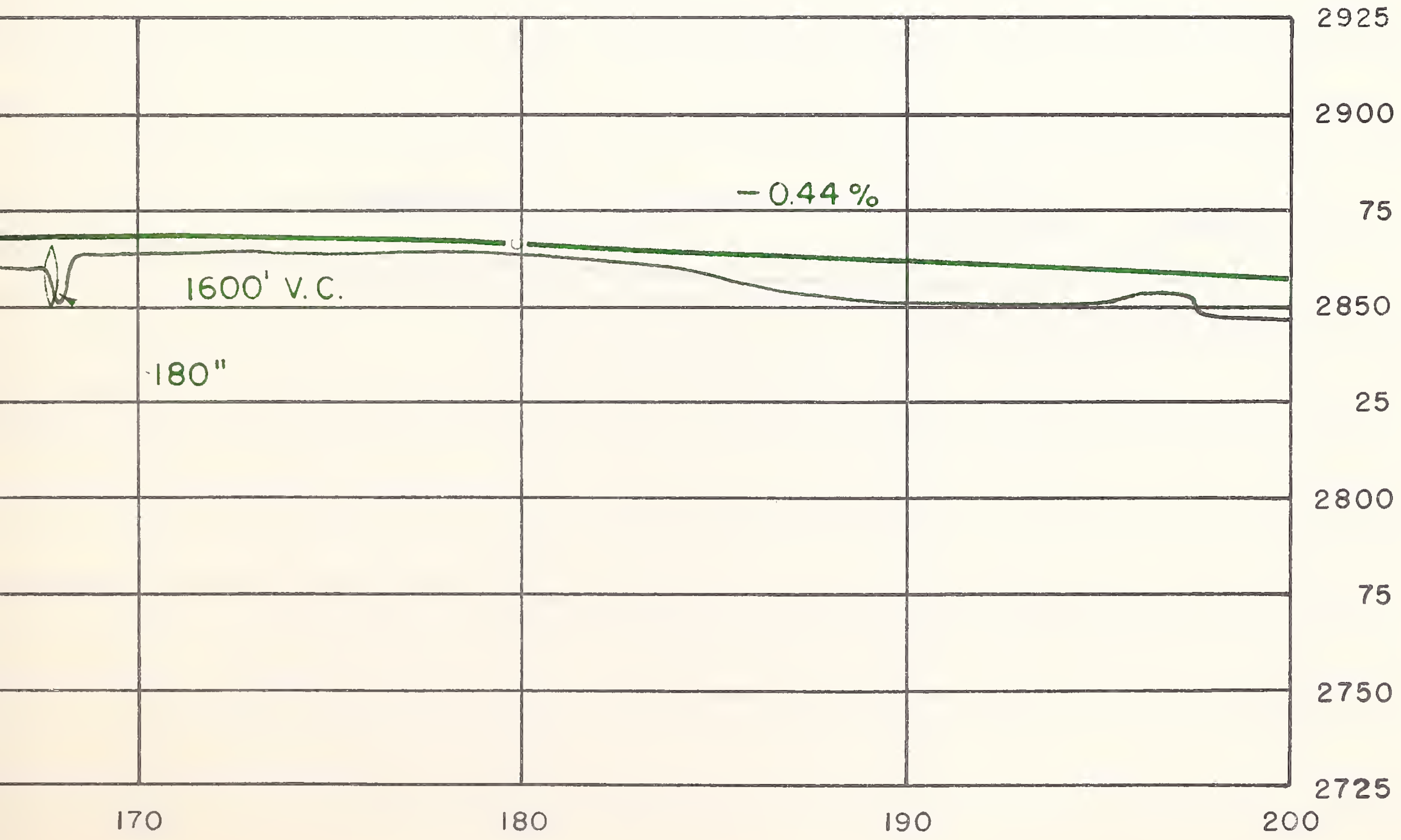
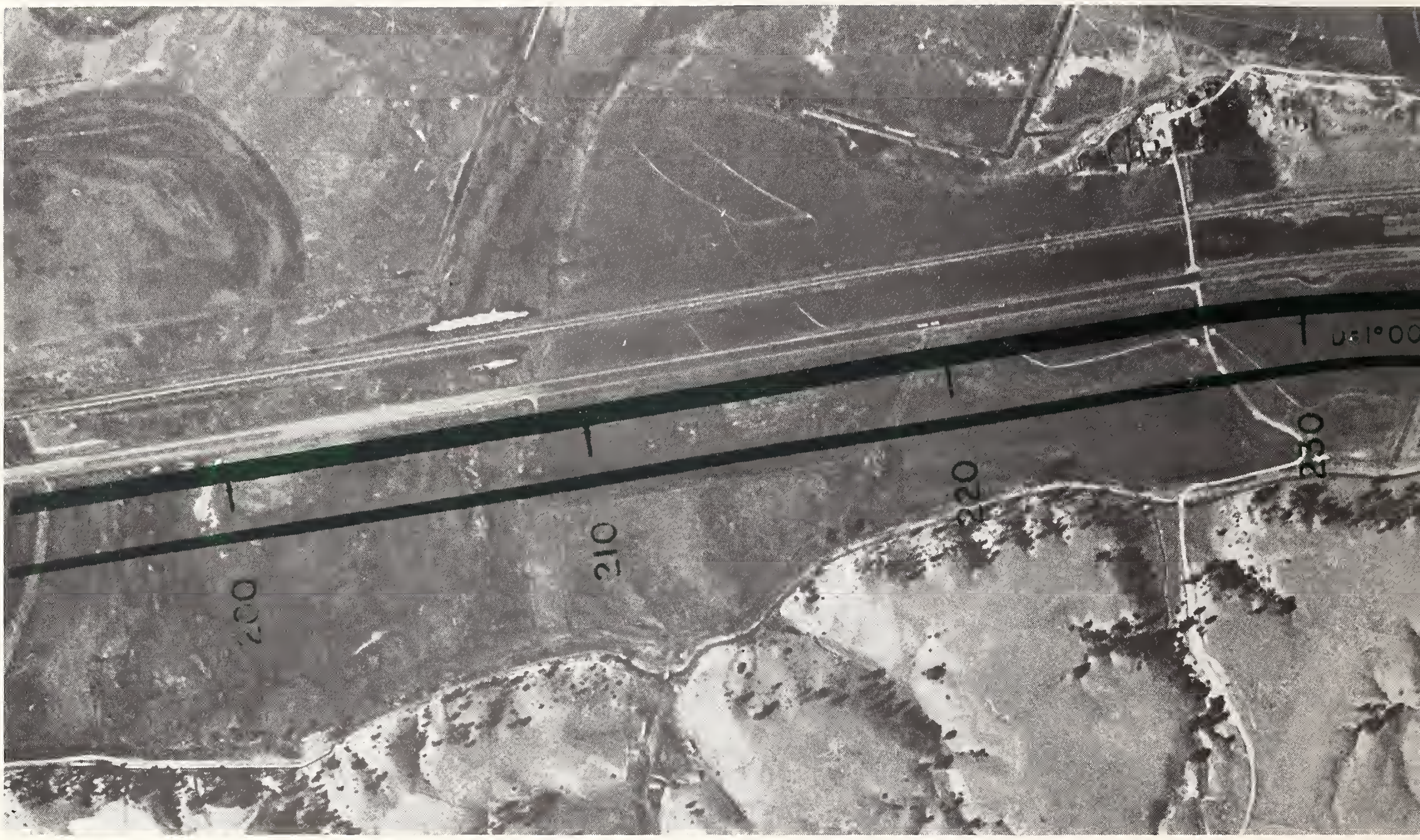

2925
2900
75
2850
25
2800
75
2750
2725
−0.44 %
1600' V. C.
180"
170
180
190
200

FIGURE 51


D=1°00
200
210
220
230

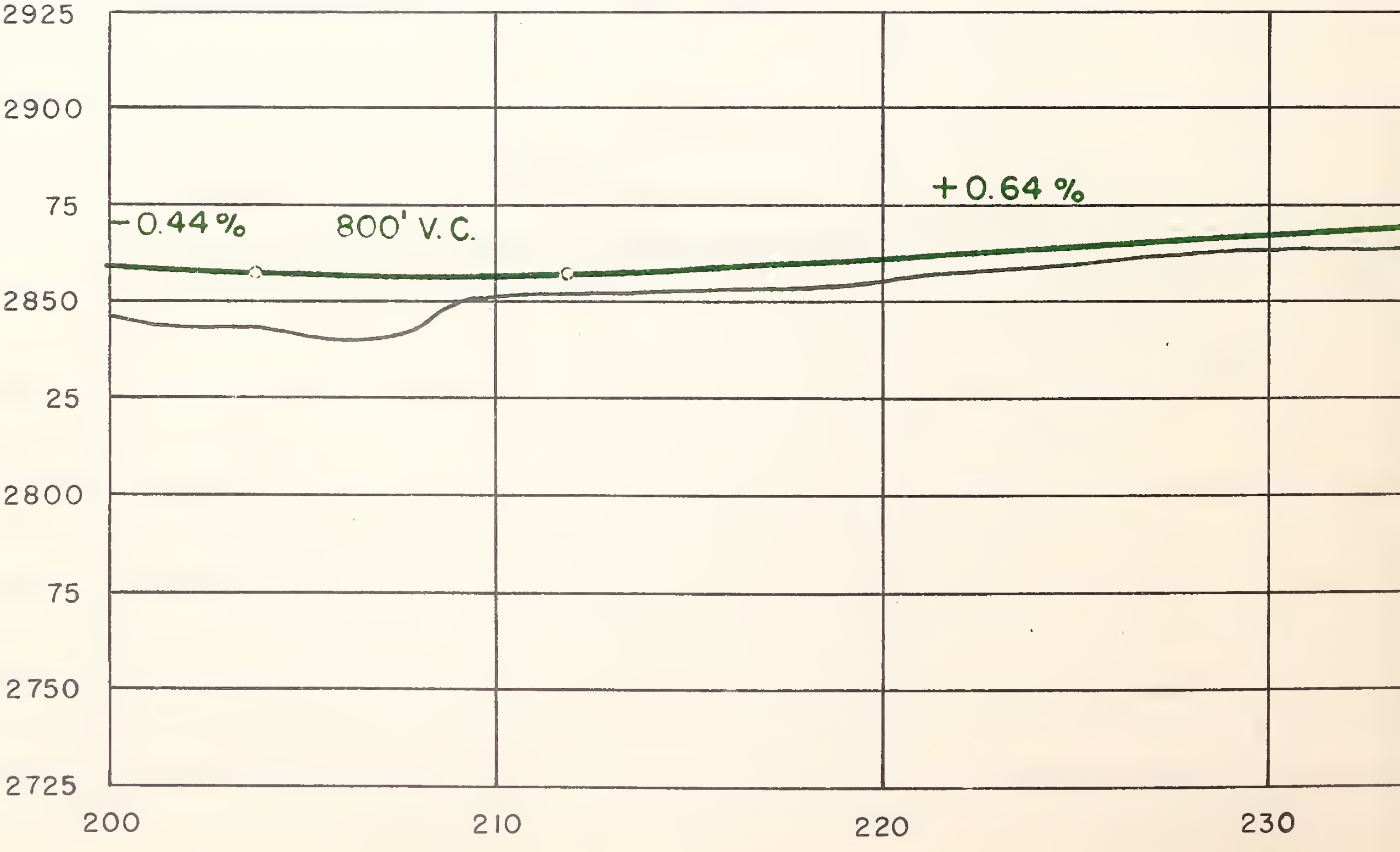

2925
2900
75
2850
25
2800
75
2750
2725
200
210
220
230
-0.44 %
800' V. C.
+0.64 %

FIGURE 52

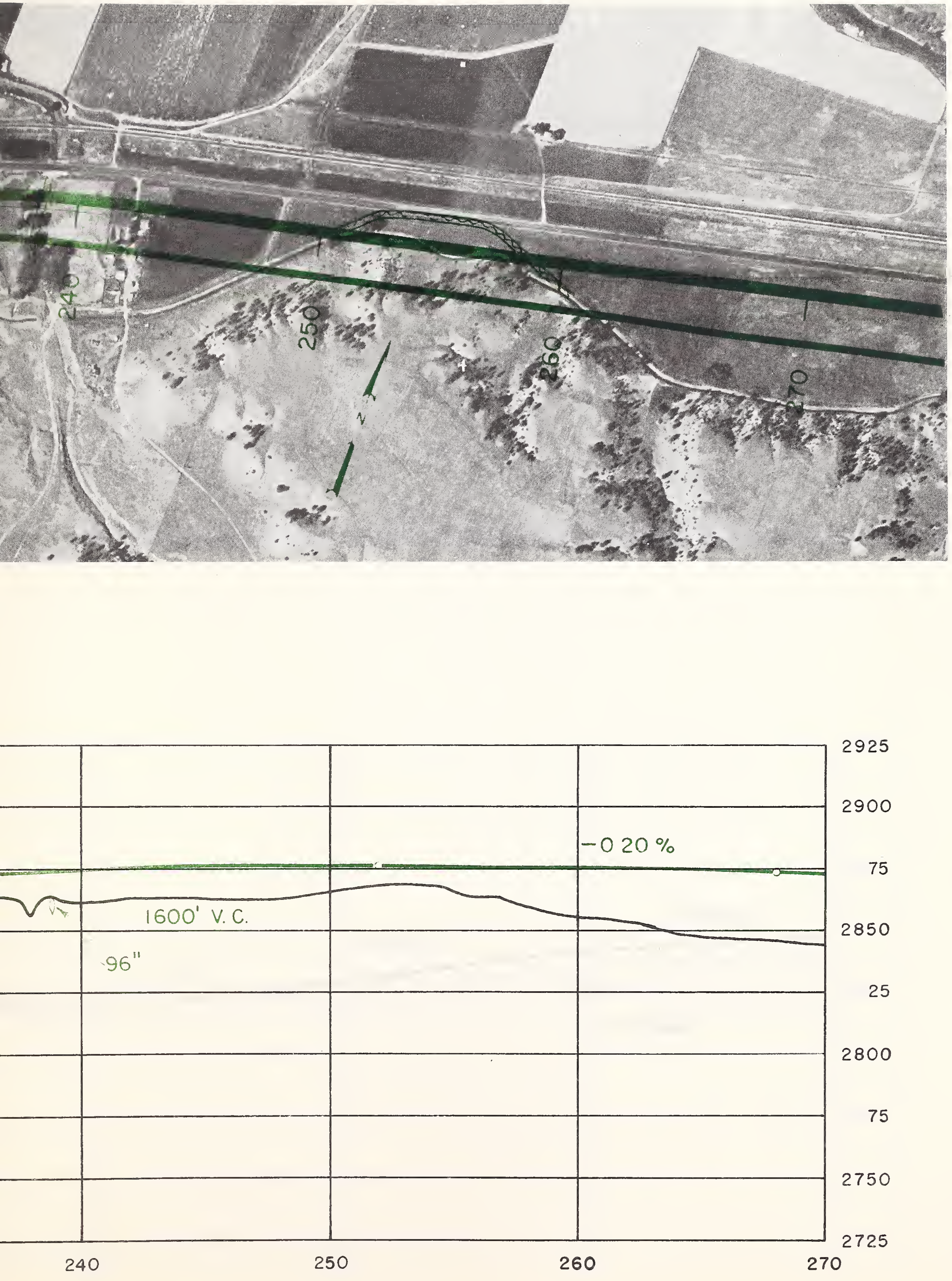

N
−0 20 %
1600' V. C.
96"

FIGURE 53

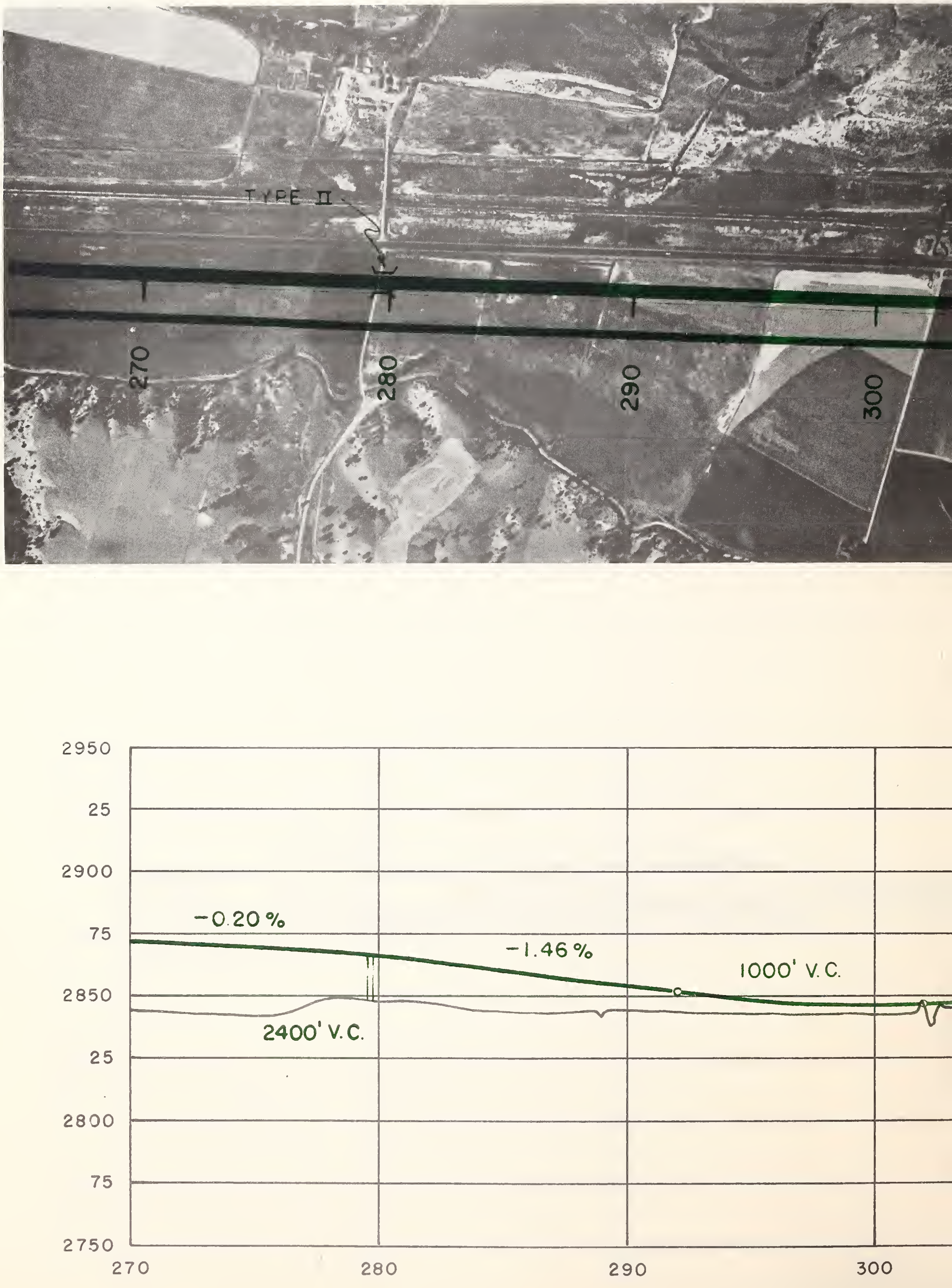

TYPE II
270
280
290
300
2950
25
2900
75
2850
25
2800
75
2750
270
280
290
300
-0.20 %
-1.46 %
1000' V.C.
2400' V.C.

FIGURE 54

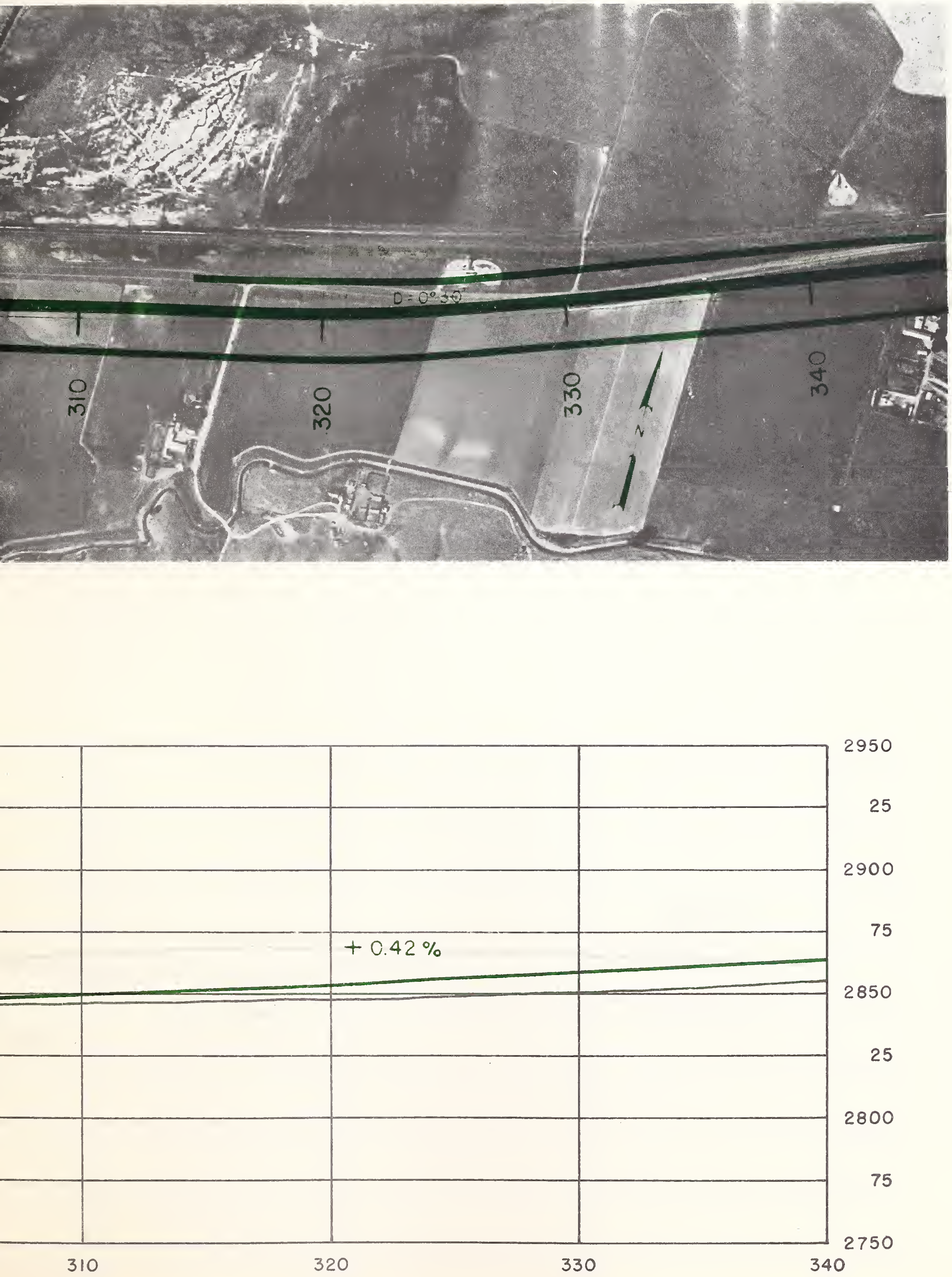

D = 0°30'
N
310
320
330
340
+ 0.42 %
2950
25
2900
75
2850
25
2800
75
2750
310
320
330
340

FIGURE 55

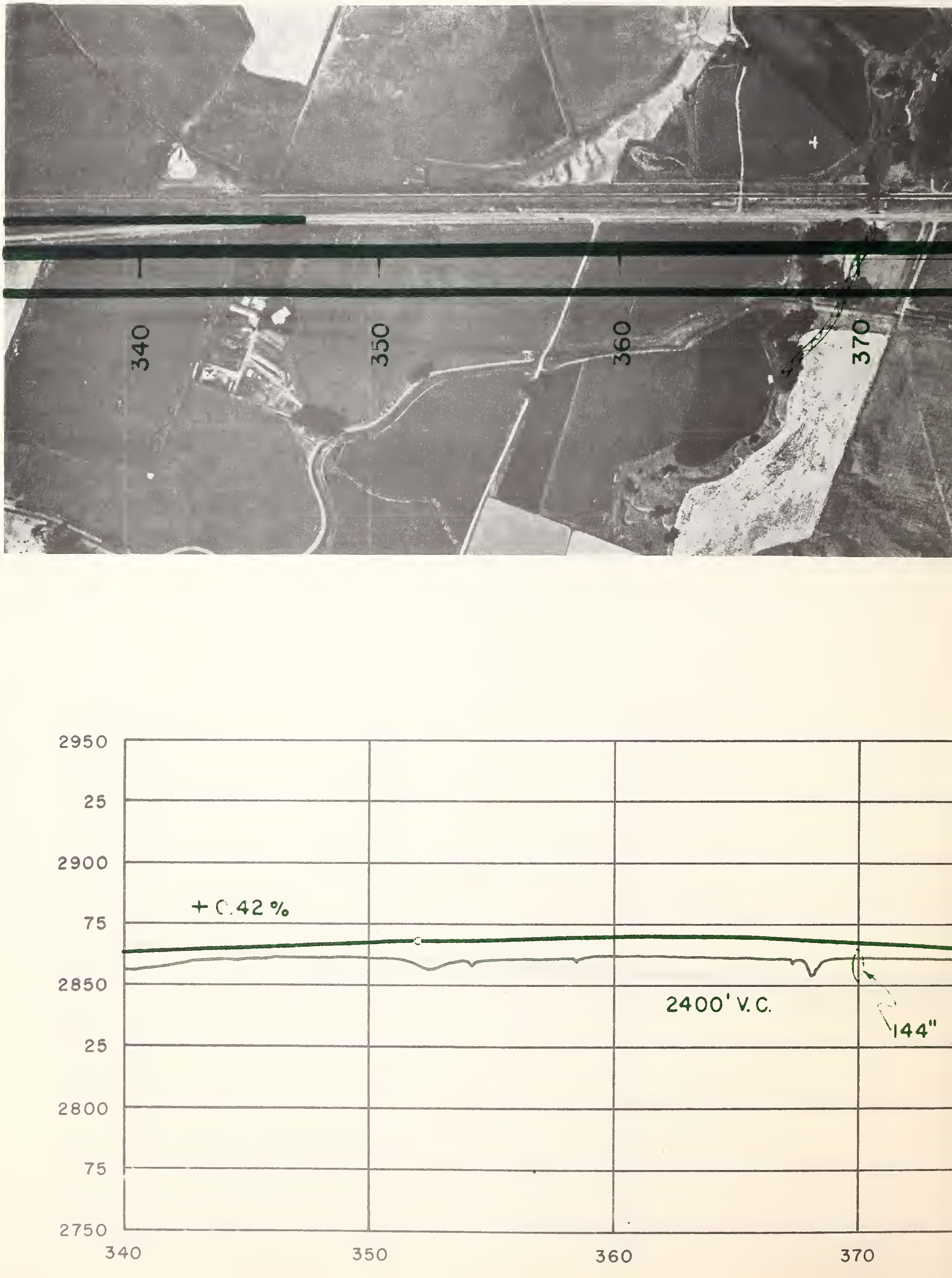
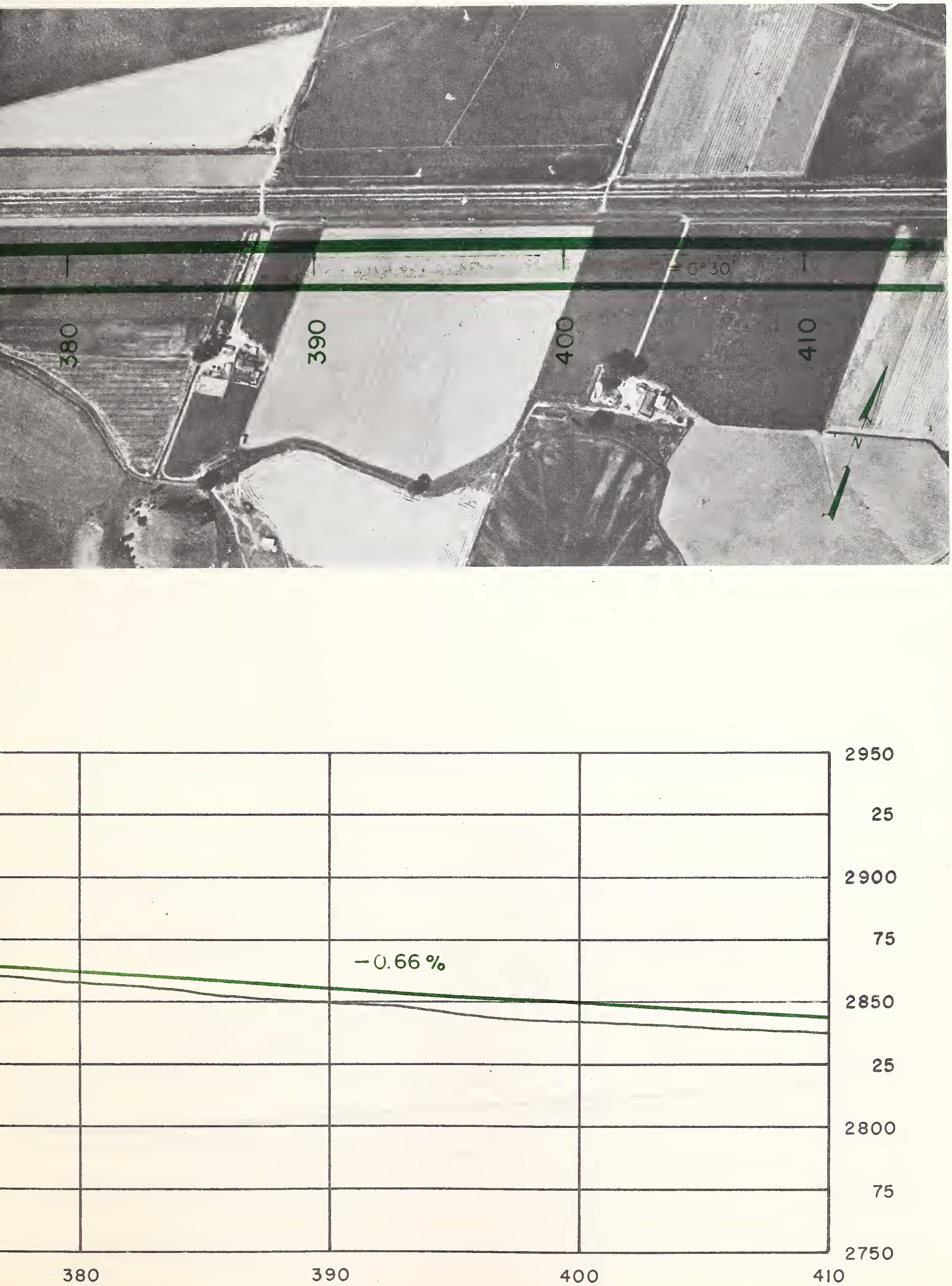

340
350
360
370
2950
25
2900
75
2850
25
2800
75
2750
340
350
360
370
+ 0.42 %
2400' V. C.
144"

FIGURE 56



380
390
400
410
0°30'
N
2950
25
2900
75
2850
25
2800
75
2750
−0.66 %
380
390
400
410

FIGURE 57

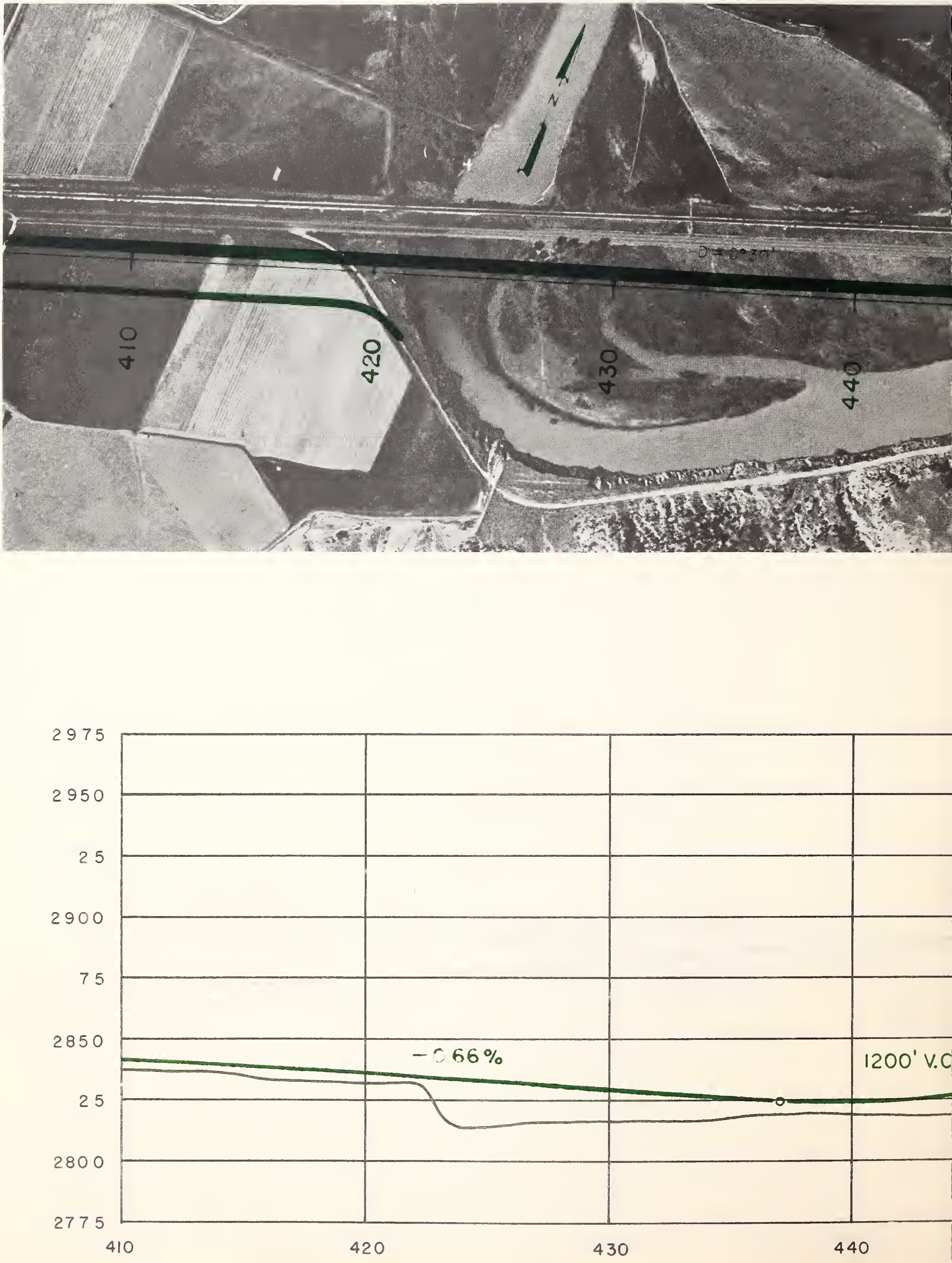
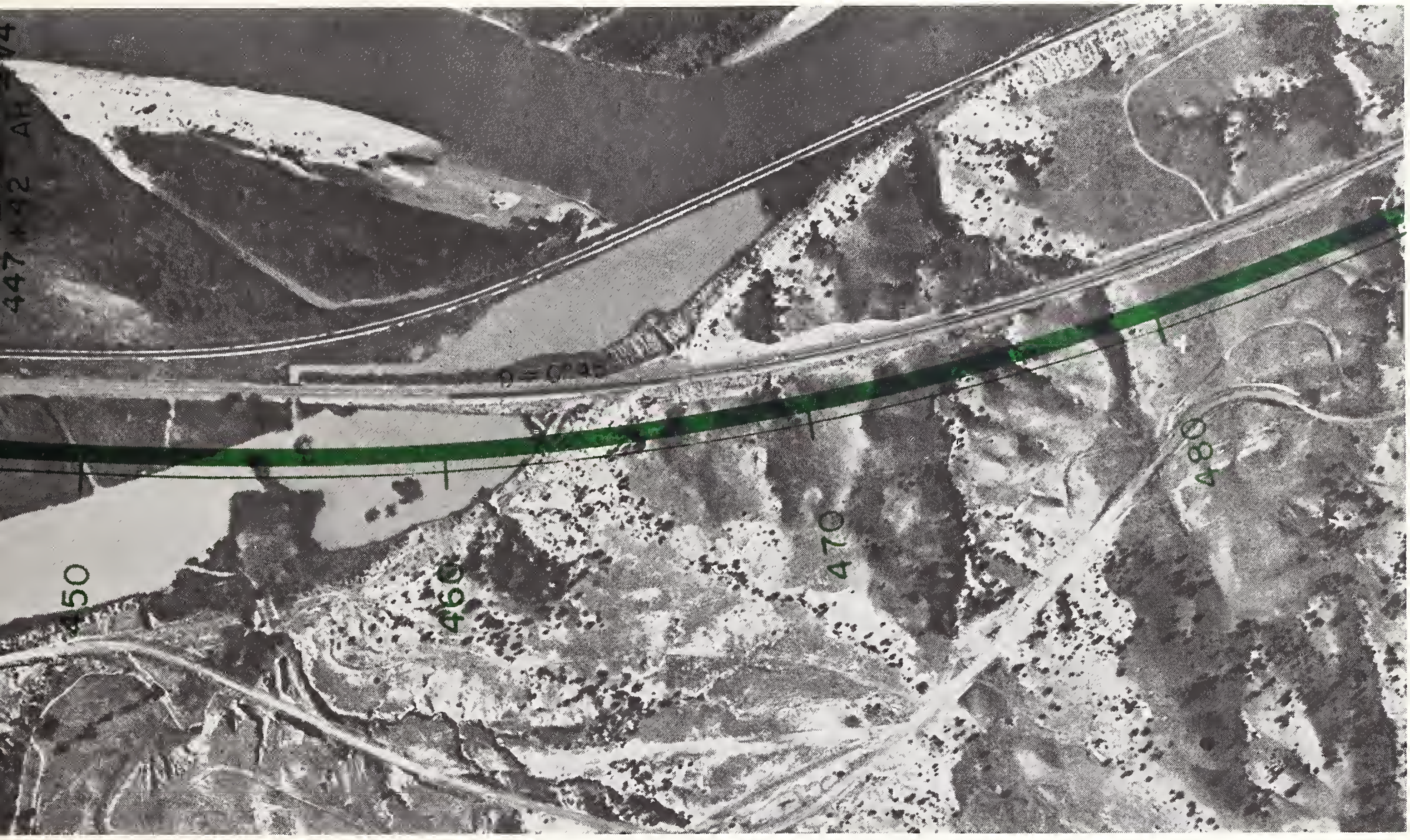
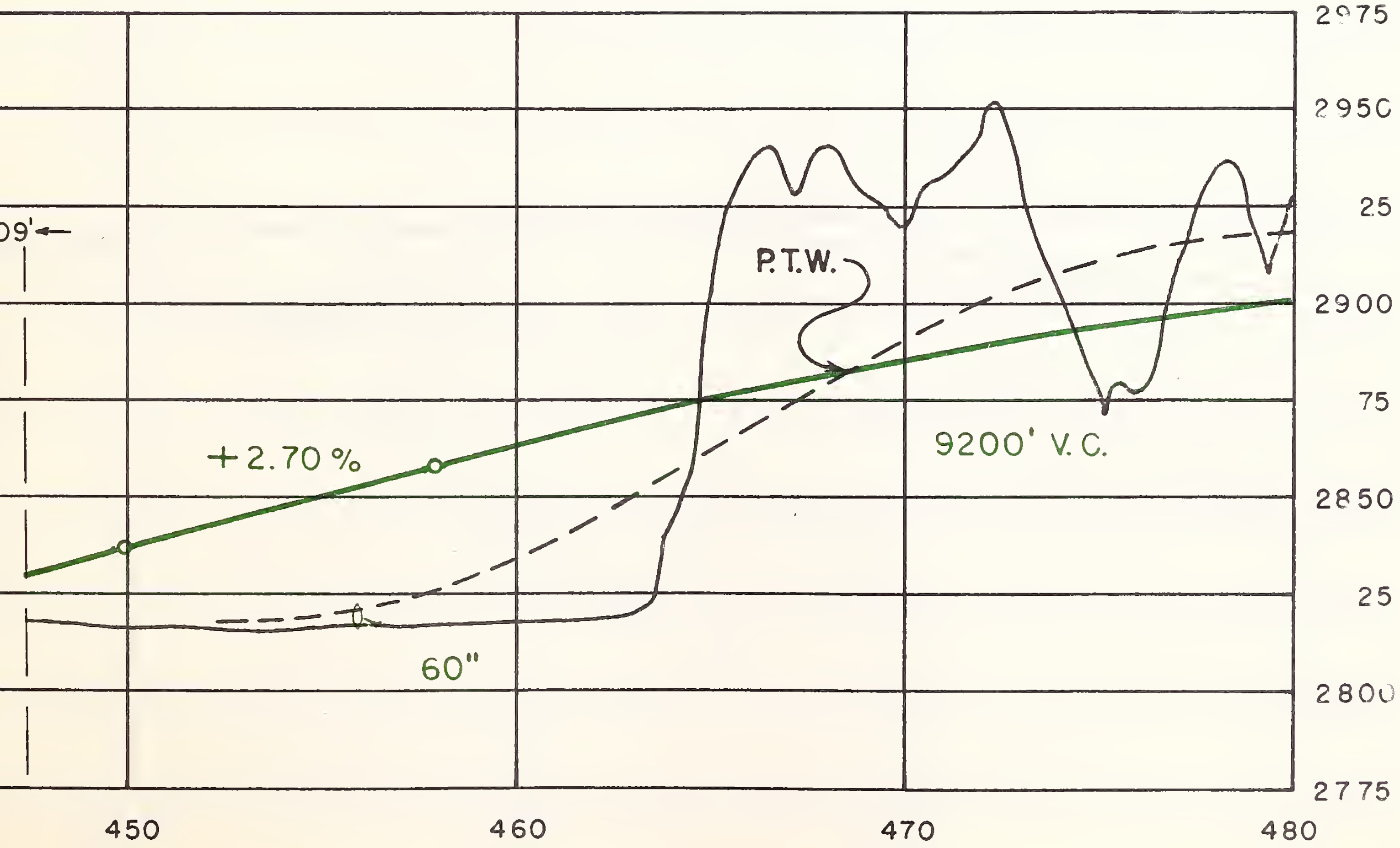

N
D = 0°30'
410
420
430
440
2975
2950
25
2900
75
2850
25
2800
2775
−0.66%
1200' V.C
410
420
430
440

FIGURE 58



447+42 AH
Δ=0°35'
450
460
470
480



09'
P.T.W.
+2.70 %
9200' V.C.
60"
2975
2950
25
2900
75
2850
25
2800
2775
450
460
470
480

FIGURE 59

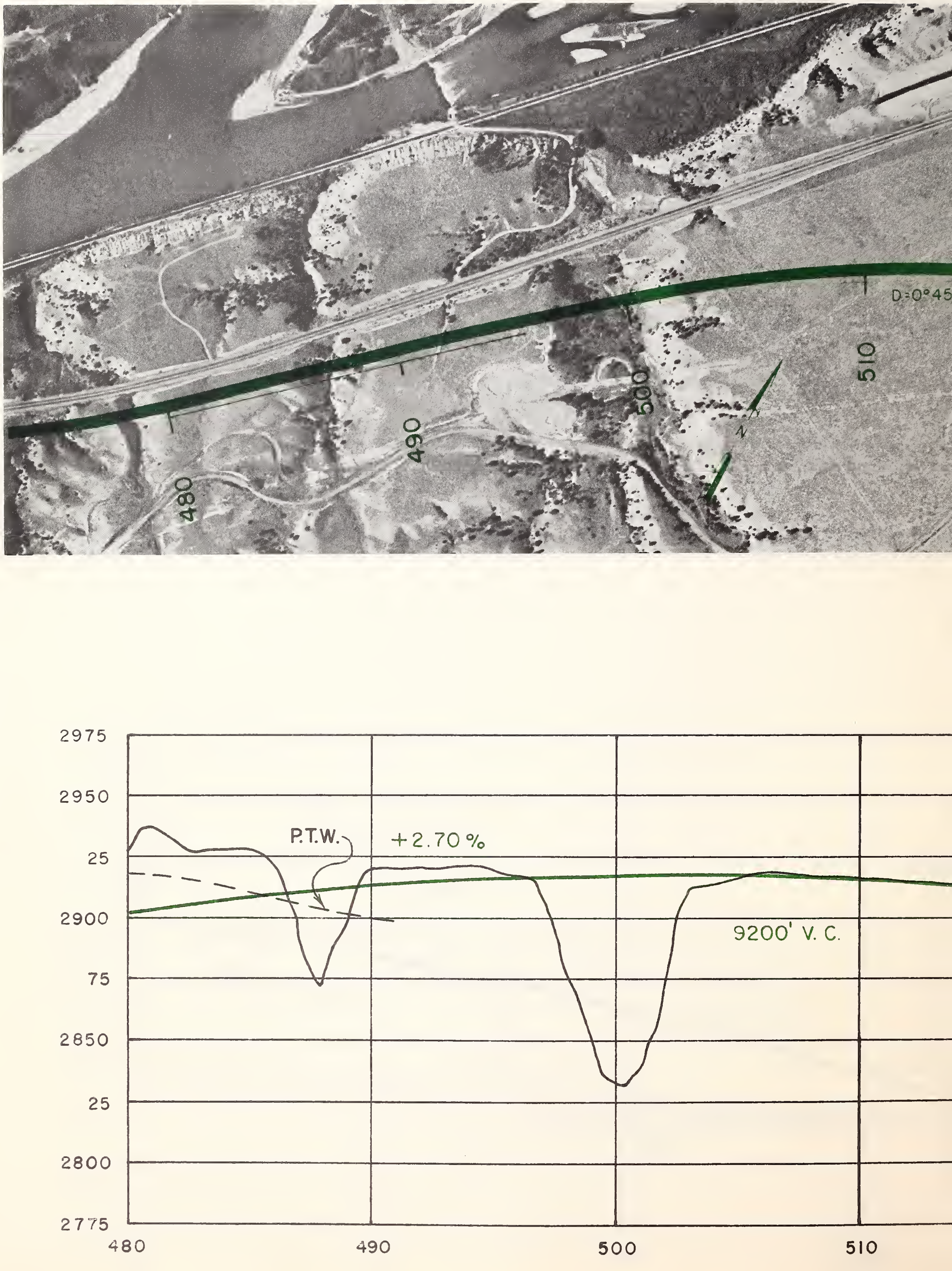
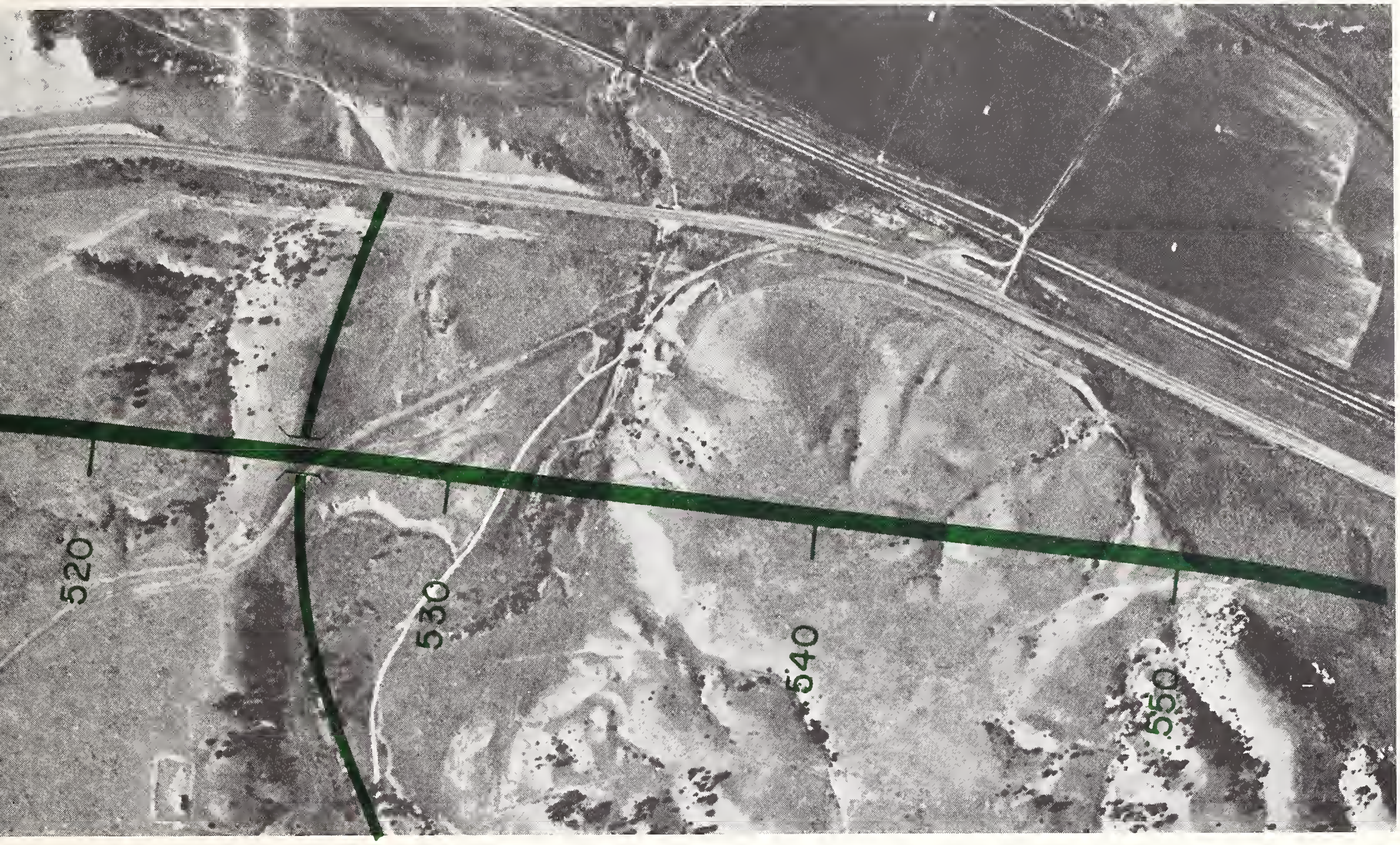
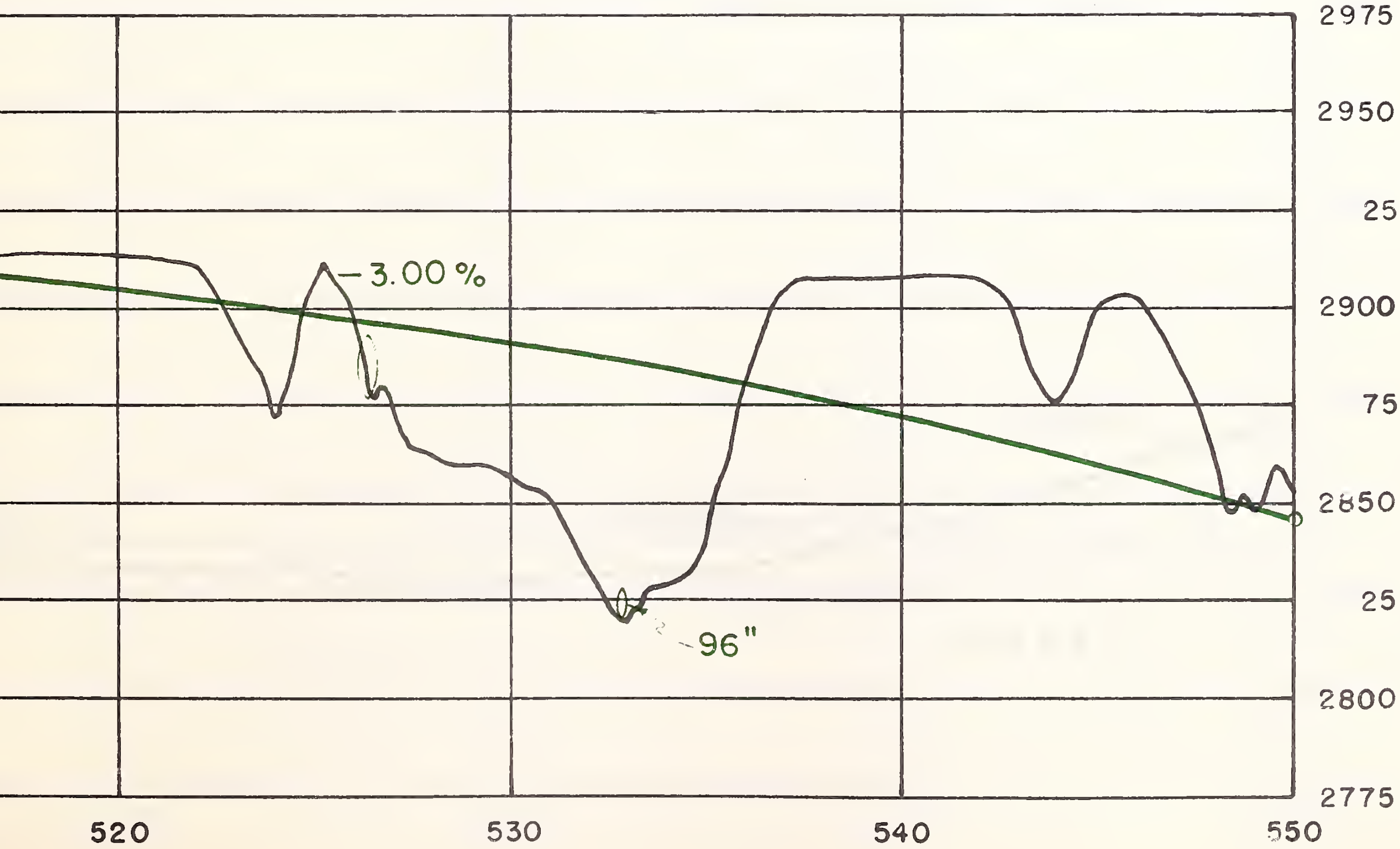

D=0°45
510
500
490
480
N
2975
2950
25
2900
75
2850
25
2800
2775
480
490
500
510
P.T.W.
+2.70 %
9200' V. C.

FIGURE 60



520
530
540
550



2975
2950
25
2900
75
2850
25
2800
2775
520
530
540
550
-3.00 %
-96"

FIGURE 61

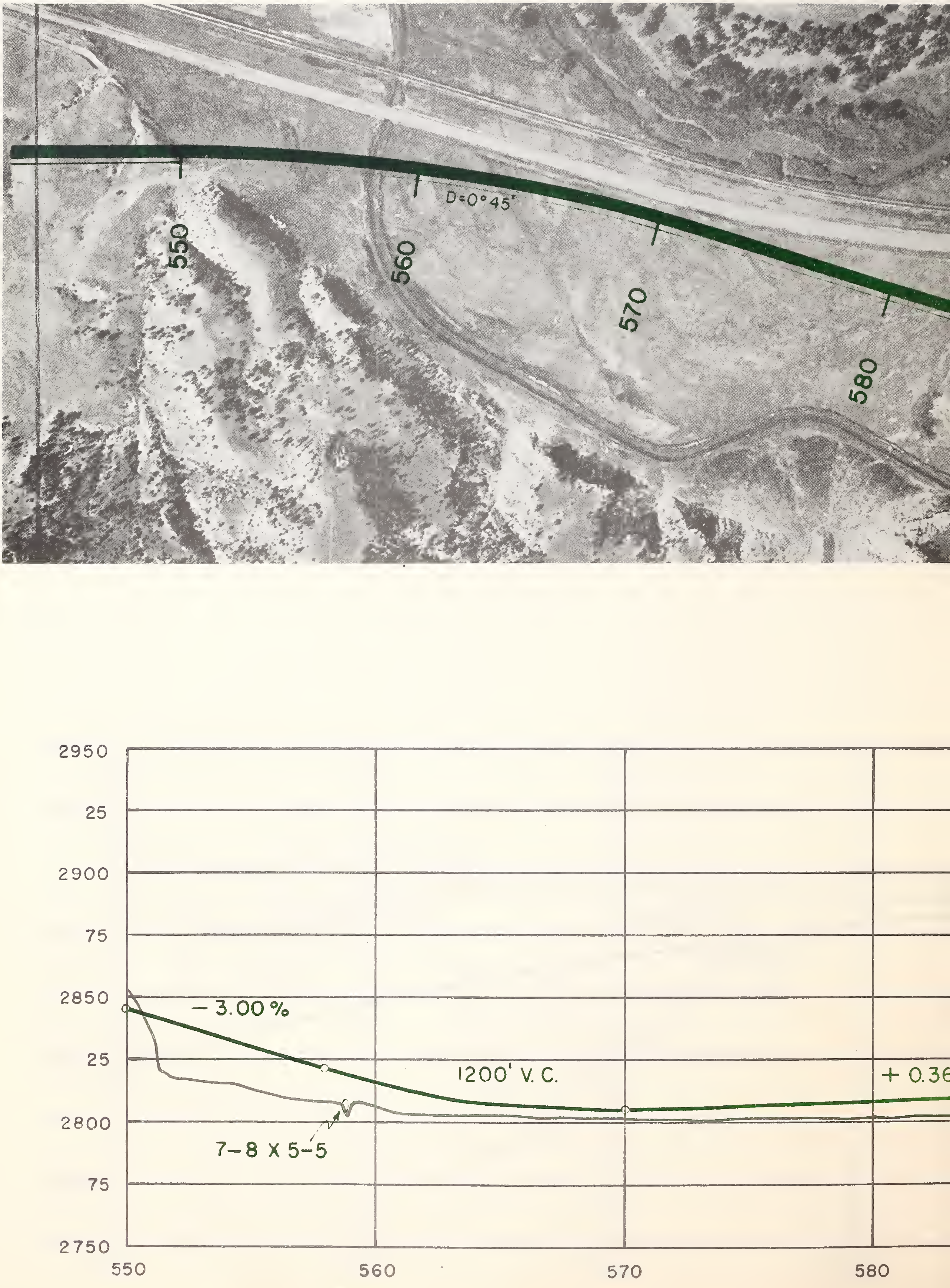
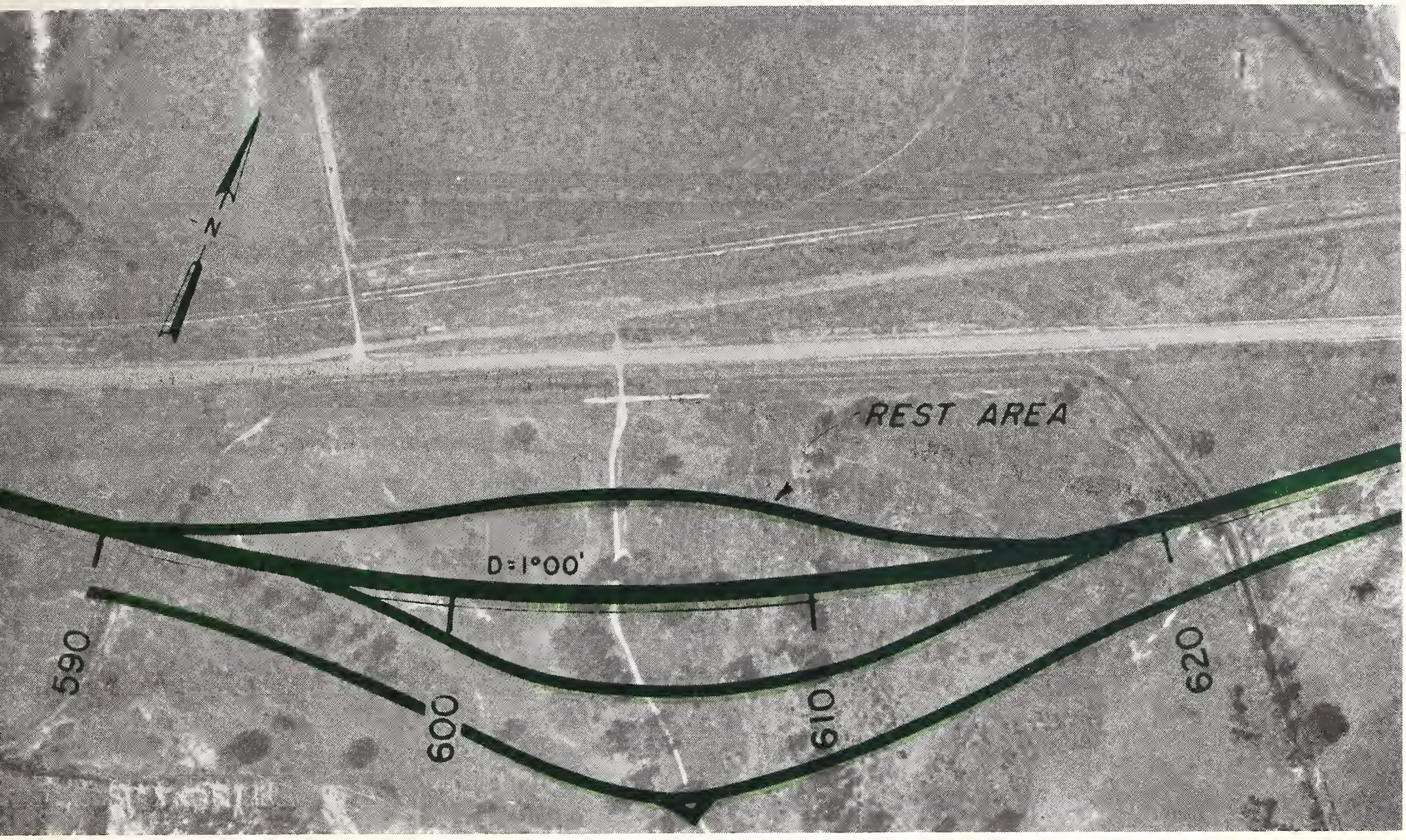

D=0°45'
550
560
570
580
2950
25
2900
75
2850
25
2800
75
2750
− 3.00 %
1200' V. C.
+ 0.36
7−8 X 5−5
550
560
570
580

FIGURE 62


N
REST AREA
D=1°00'
590
600
610
620

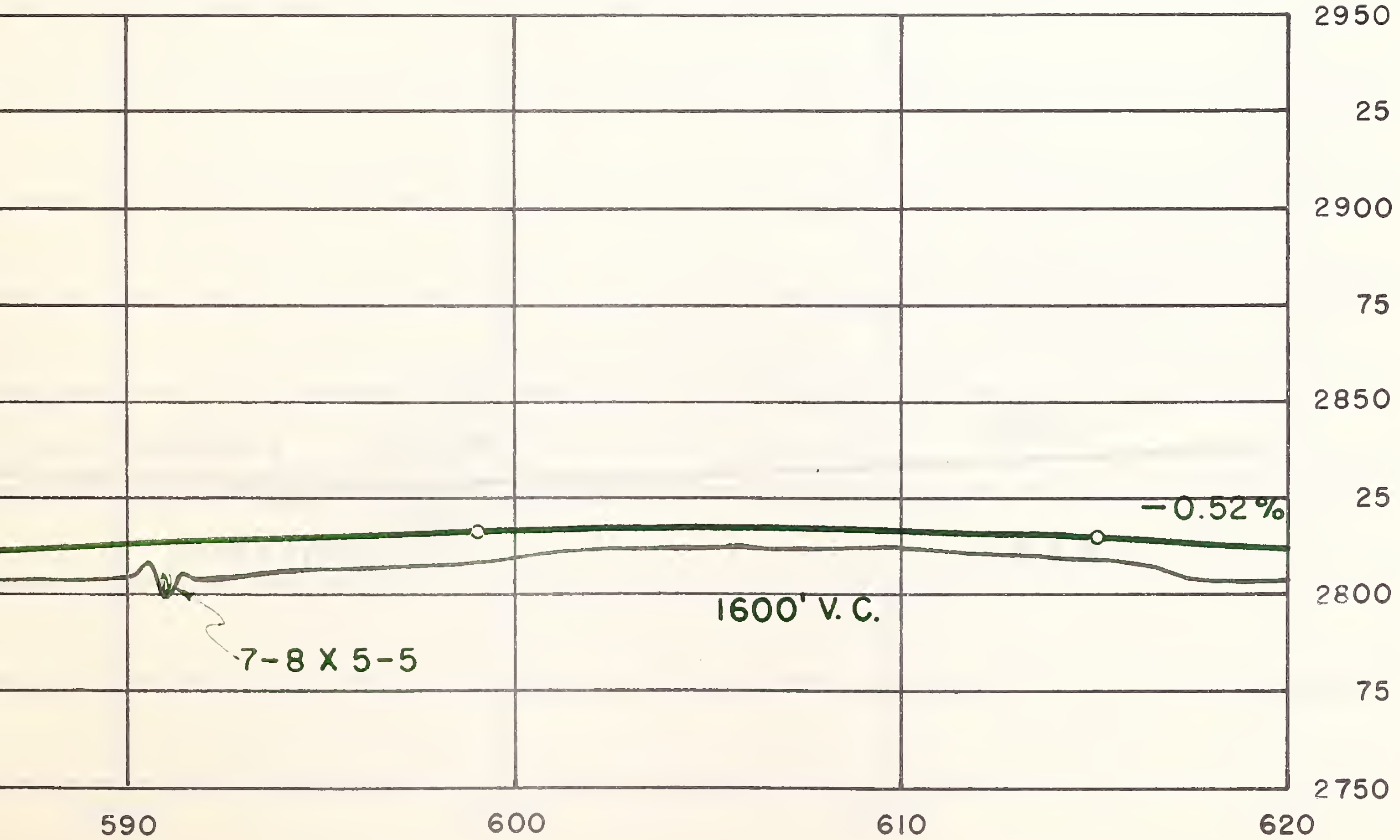
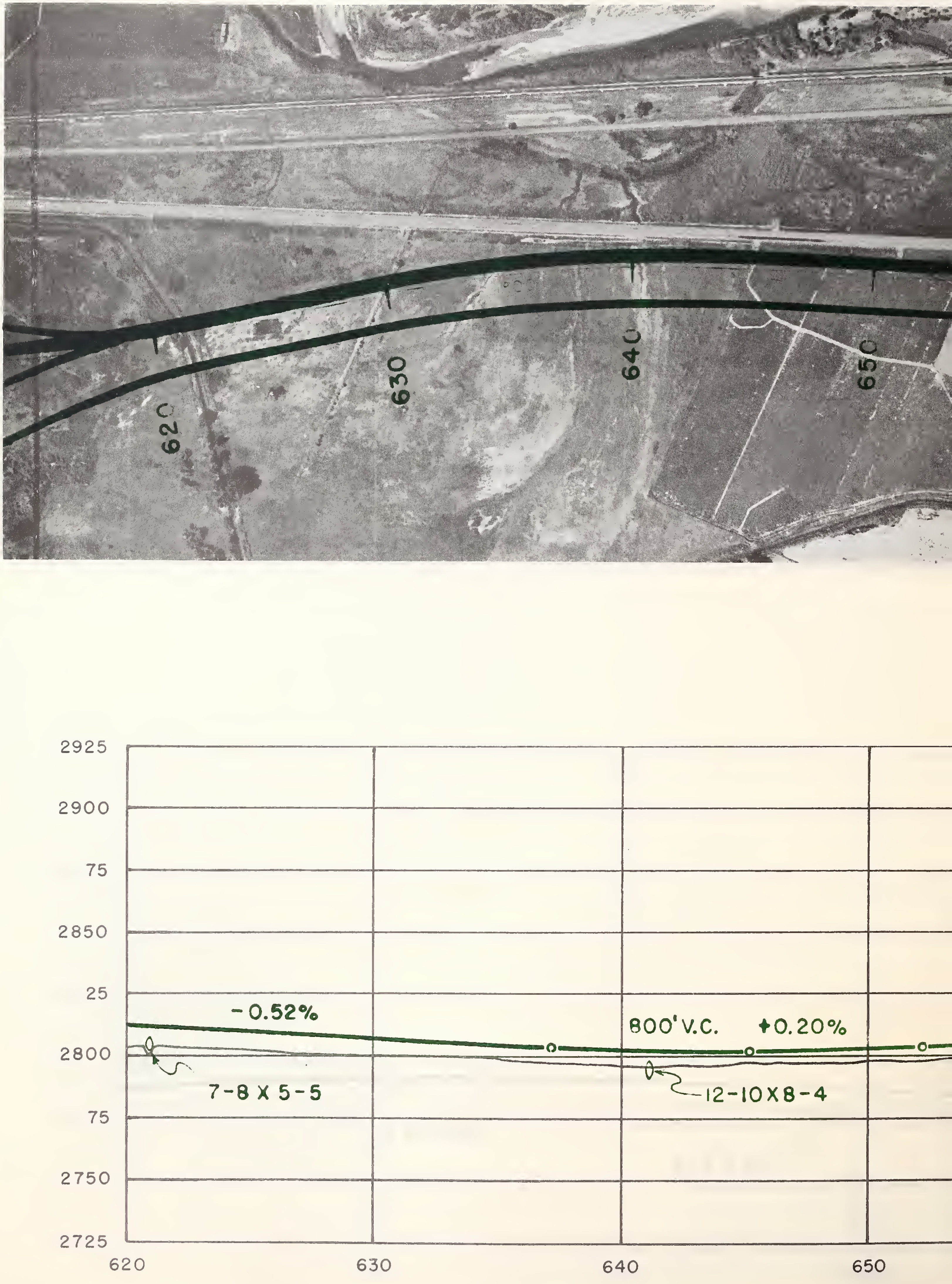

2950
25
2900
75
2850
25
2800
75
2750
−0.52%
1600' V. C.
7-8 X 5-5
590
600
610
620

FIGURE 63


620
630
640
650
2925
2900
75
2850
25
2800
75
2750
2725
620
630
640
650
-0.52%
800' V.C.
+0.20%
7-8 X 5-5
12-10X8-4

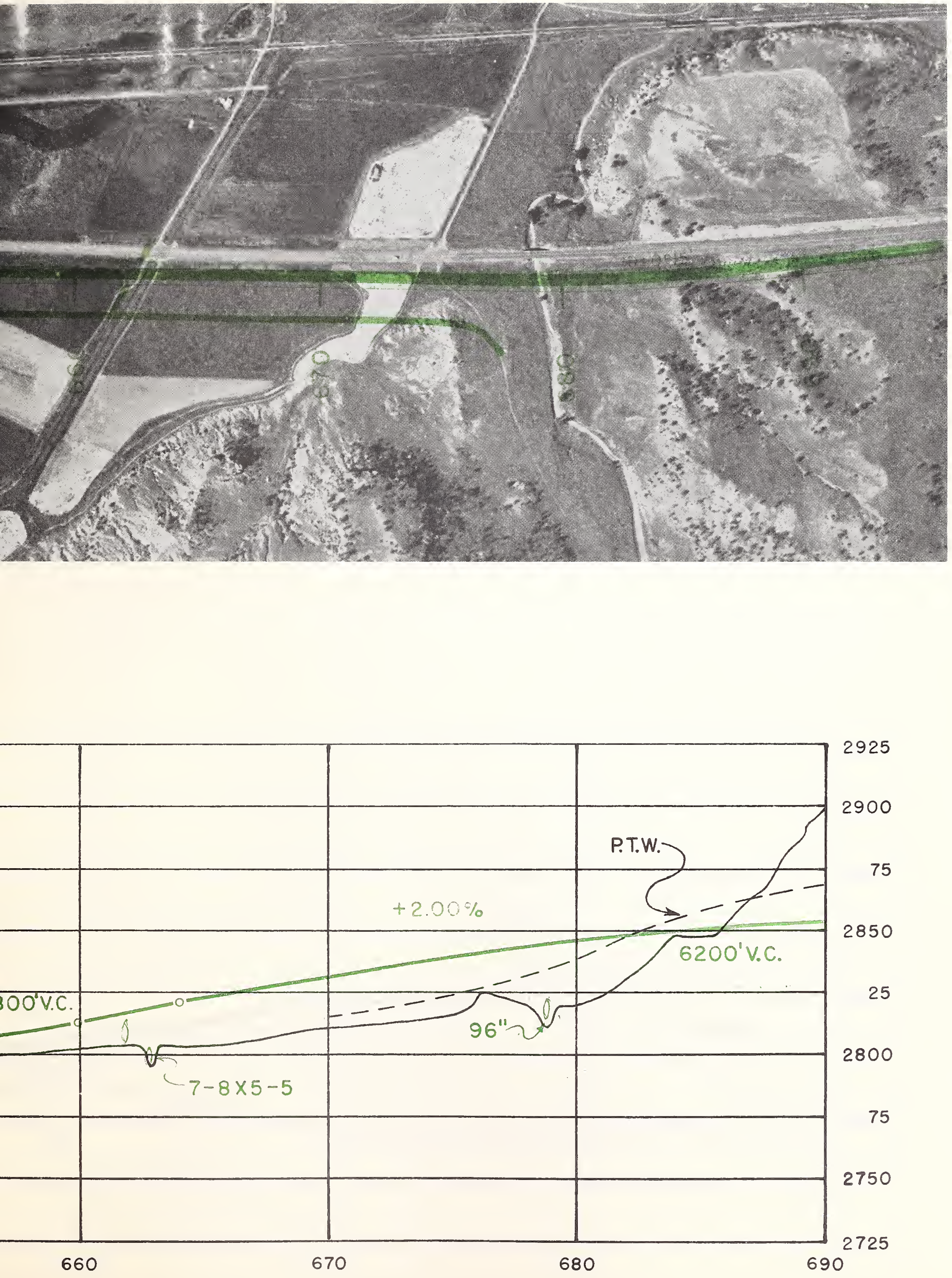
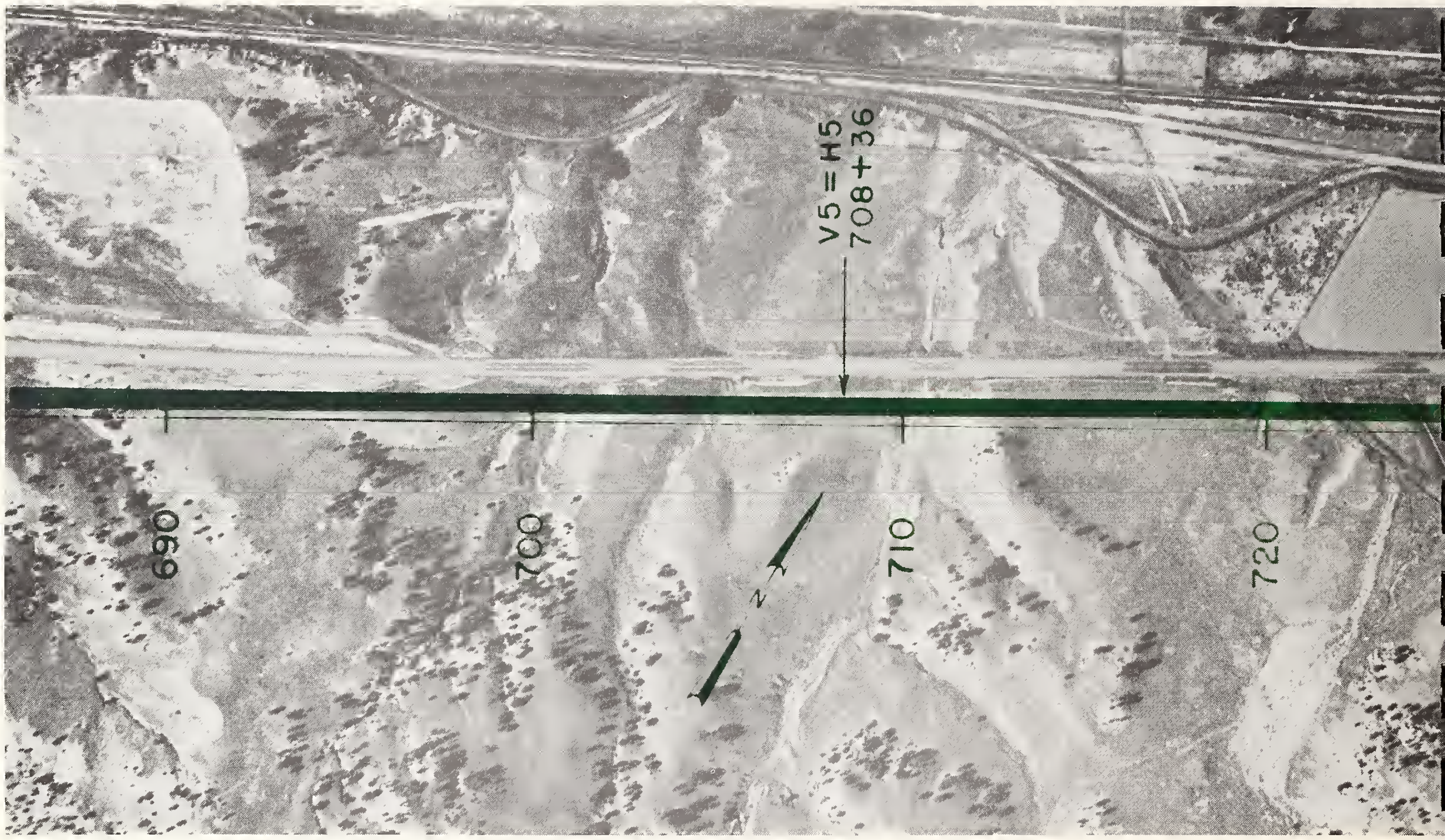

P.T.W.
+2.00%
6200'V.C.
00'V.C.
96"
7-8X5-5
2925
2900
75
2850
25
2800
75
2750
2725
660
670
680
690

FIGURE 65


V5 = H5
708+36
690
700
710
720
N

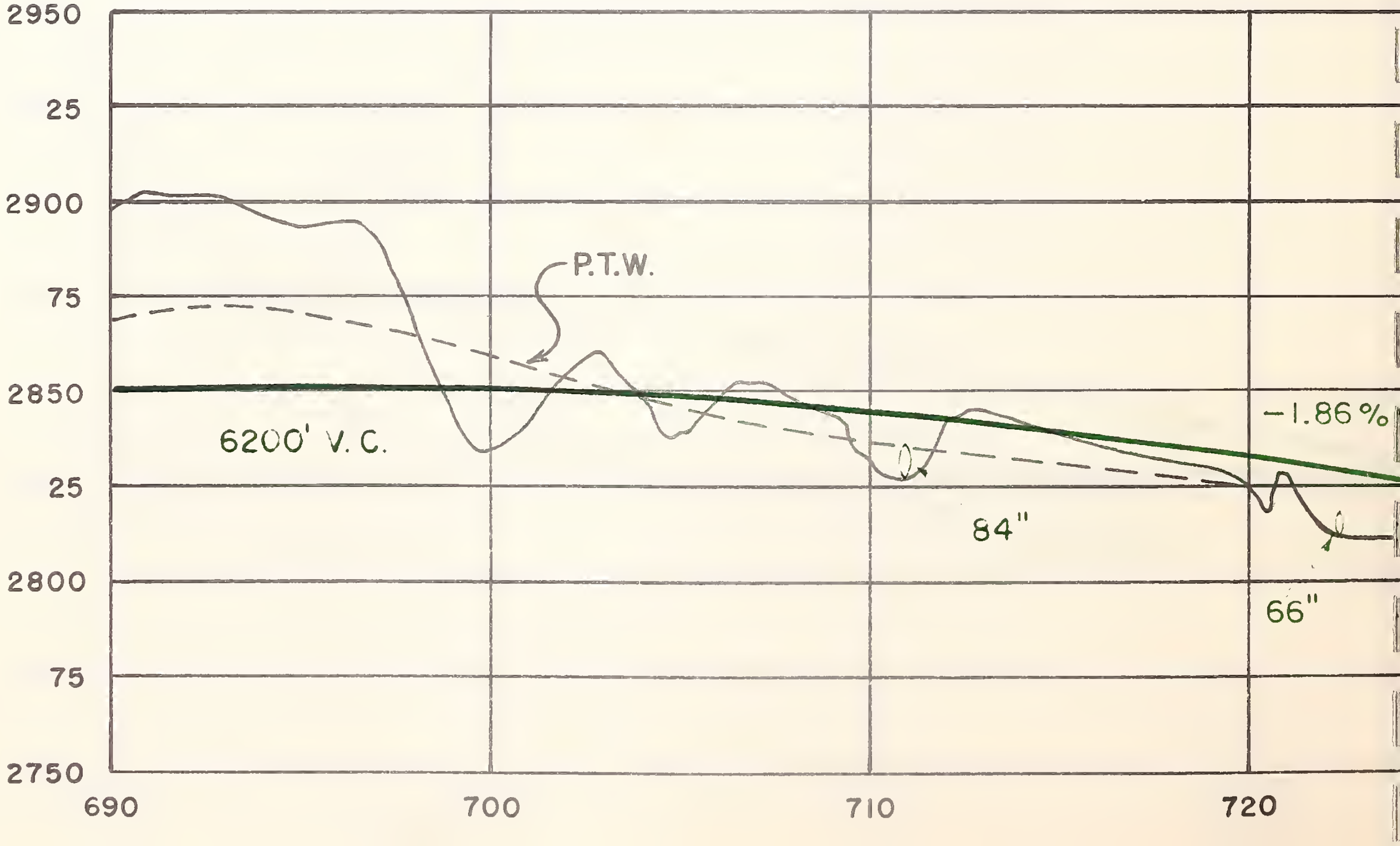

2950
25
2900
75
2850
25
2800
75
2750
690
700
710
720
P.T.W.
6200' V. C.
-1.86 %
84"
66"

FIGURE 66

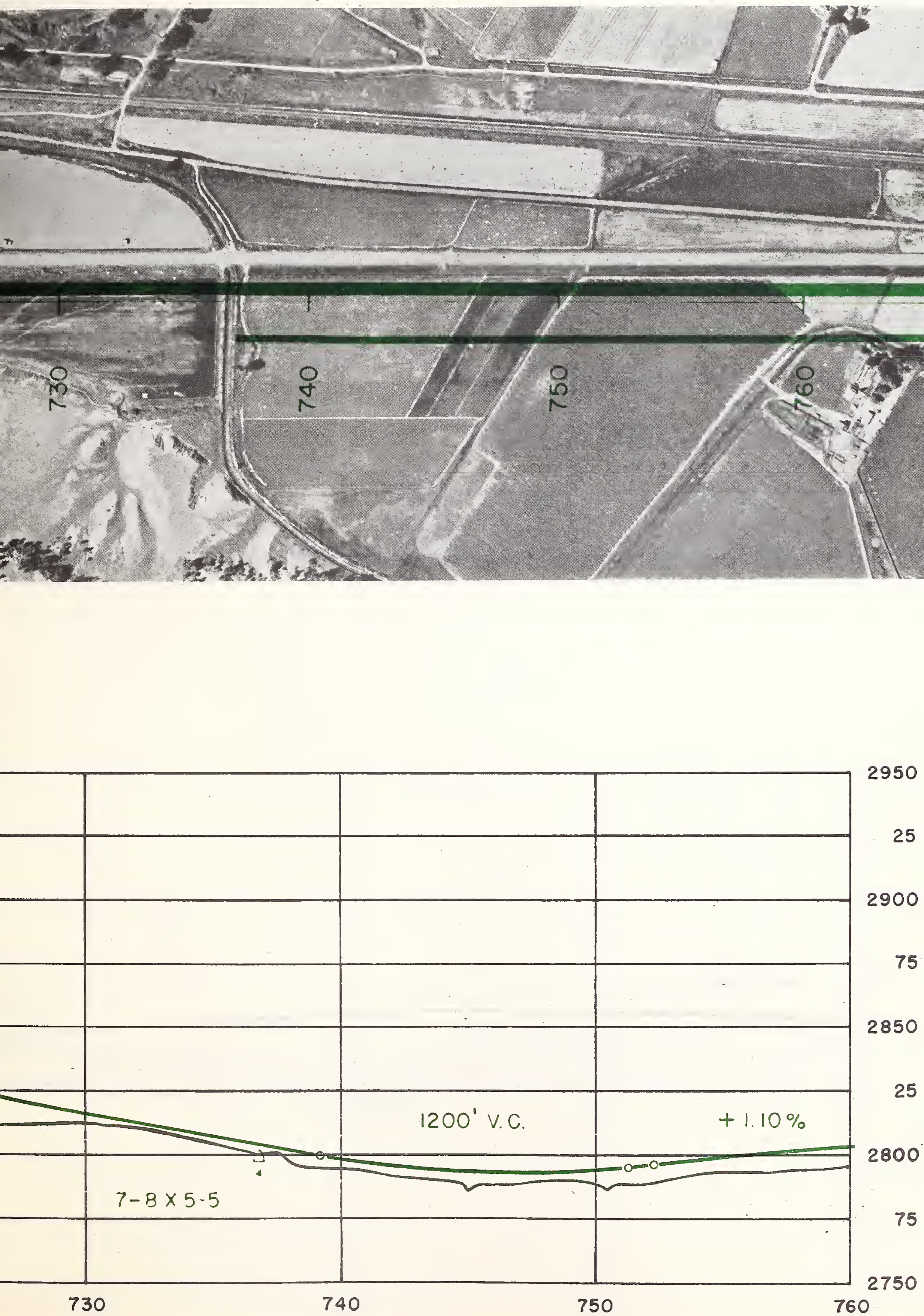
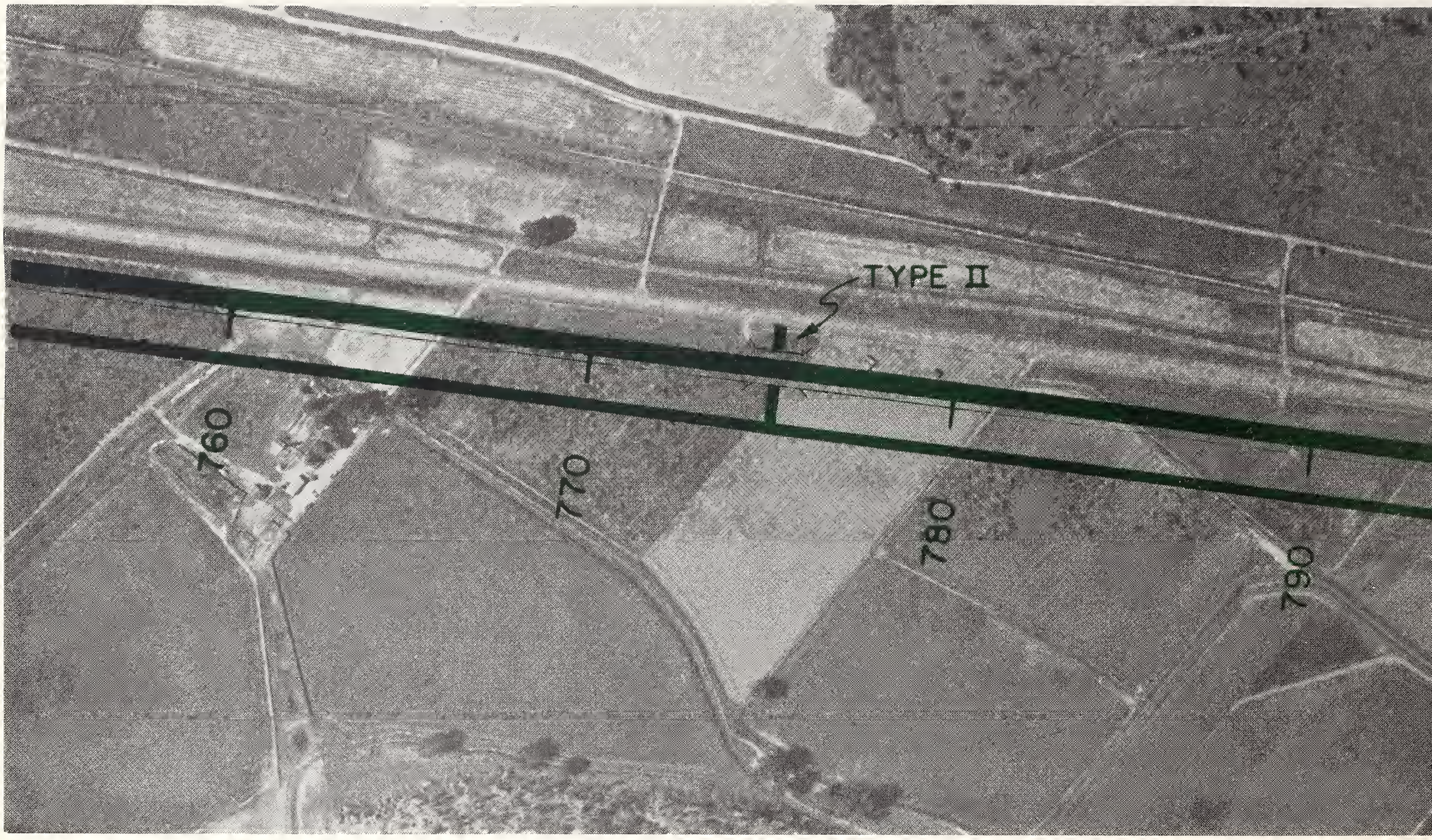

1200' V.C.
+ 1.10 %
7-8 X 5-5

FIGURE 67


TYPE II
760
770
780
790

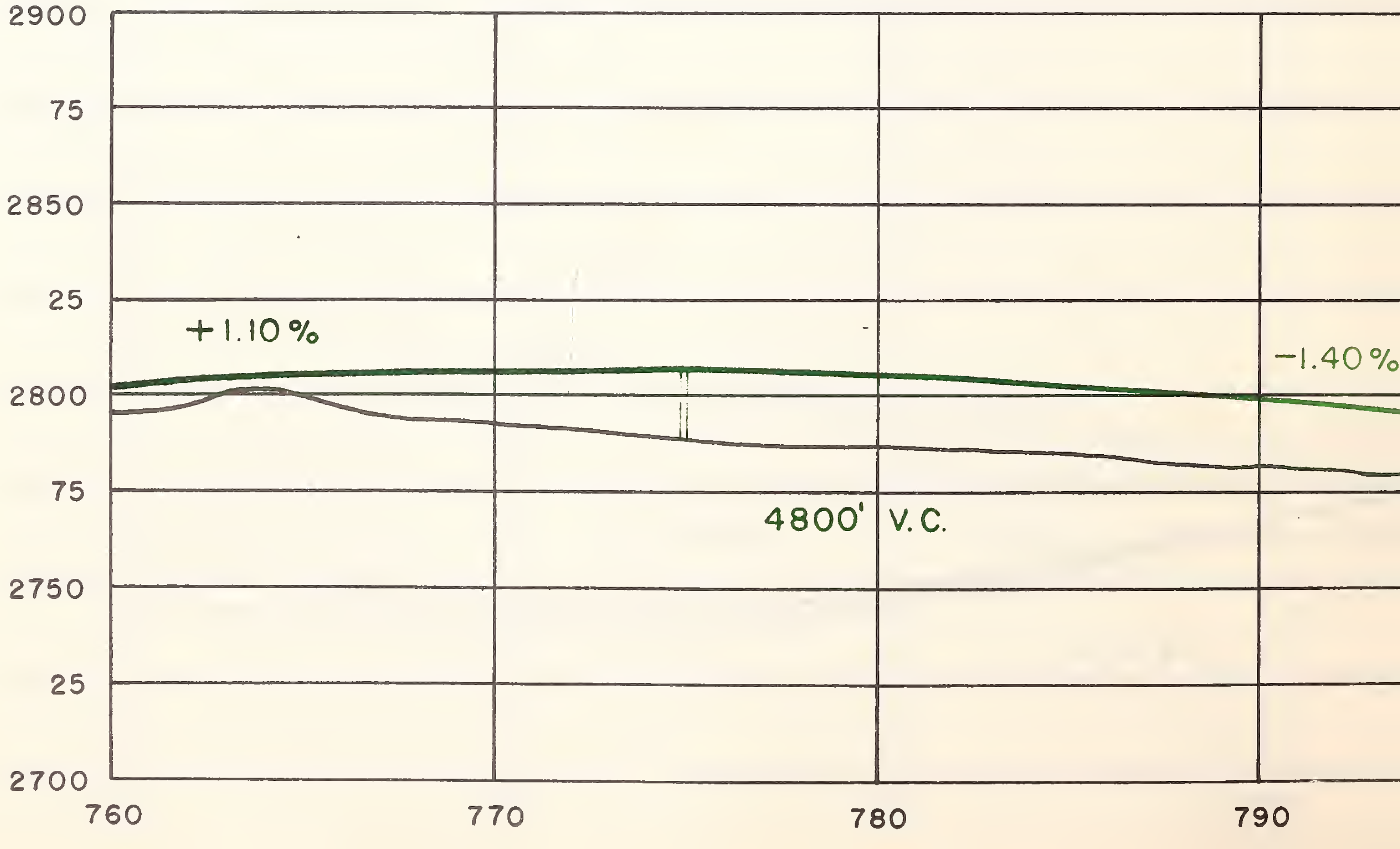

2900
75
2850
25
2800
75
2750
25
2700
+1.10 %
−1.40 %
4800' V.C.
760
770
780
790

FIGURE 68

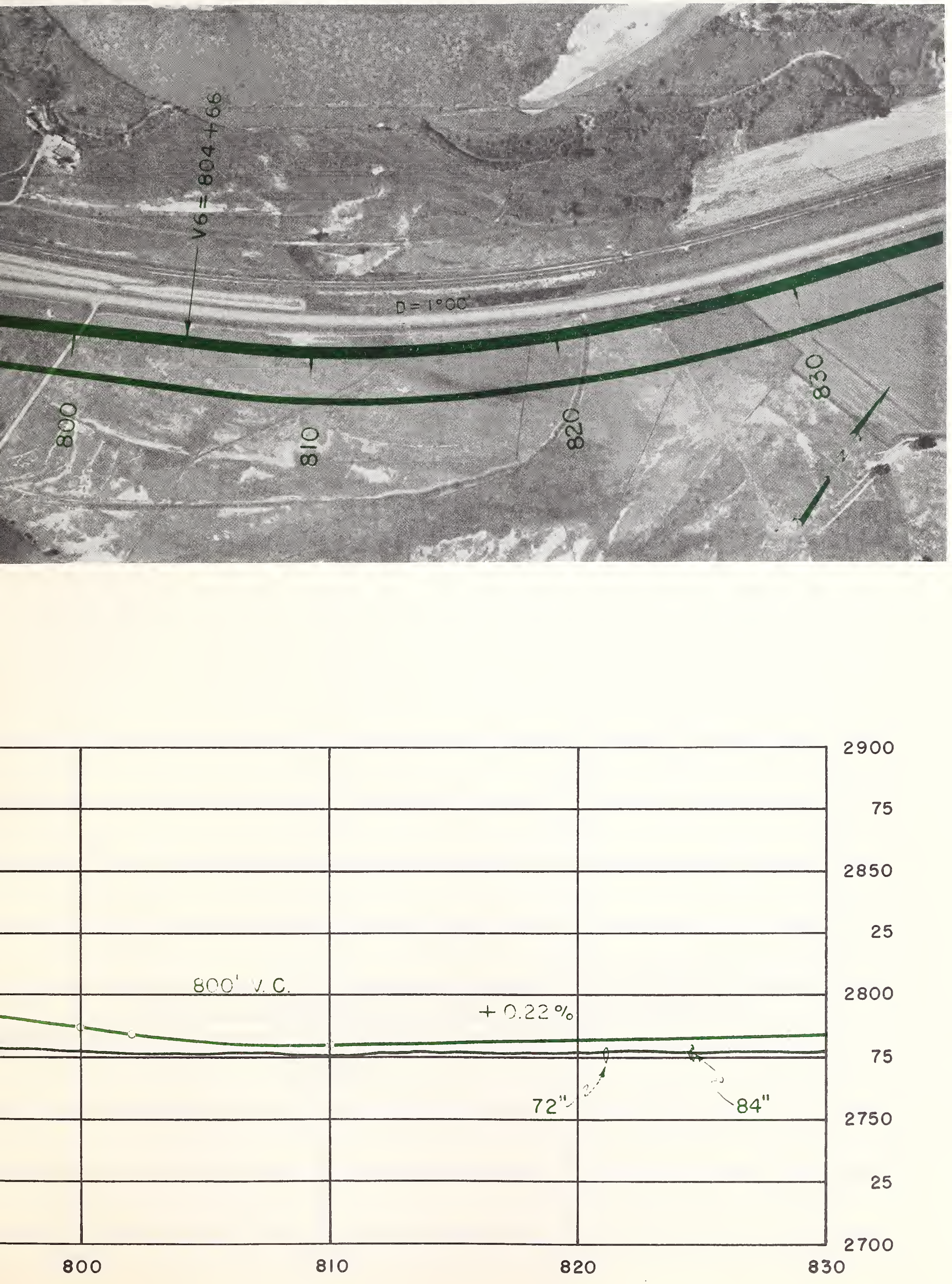
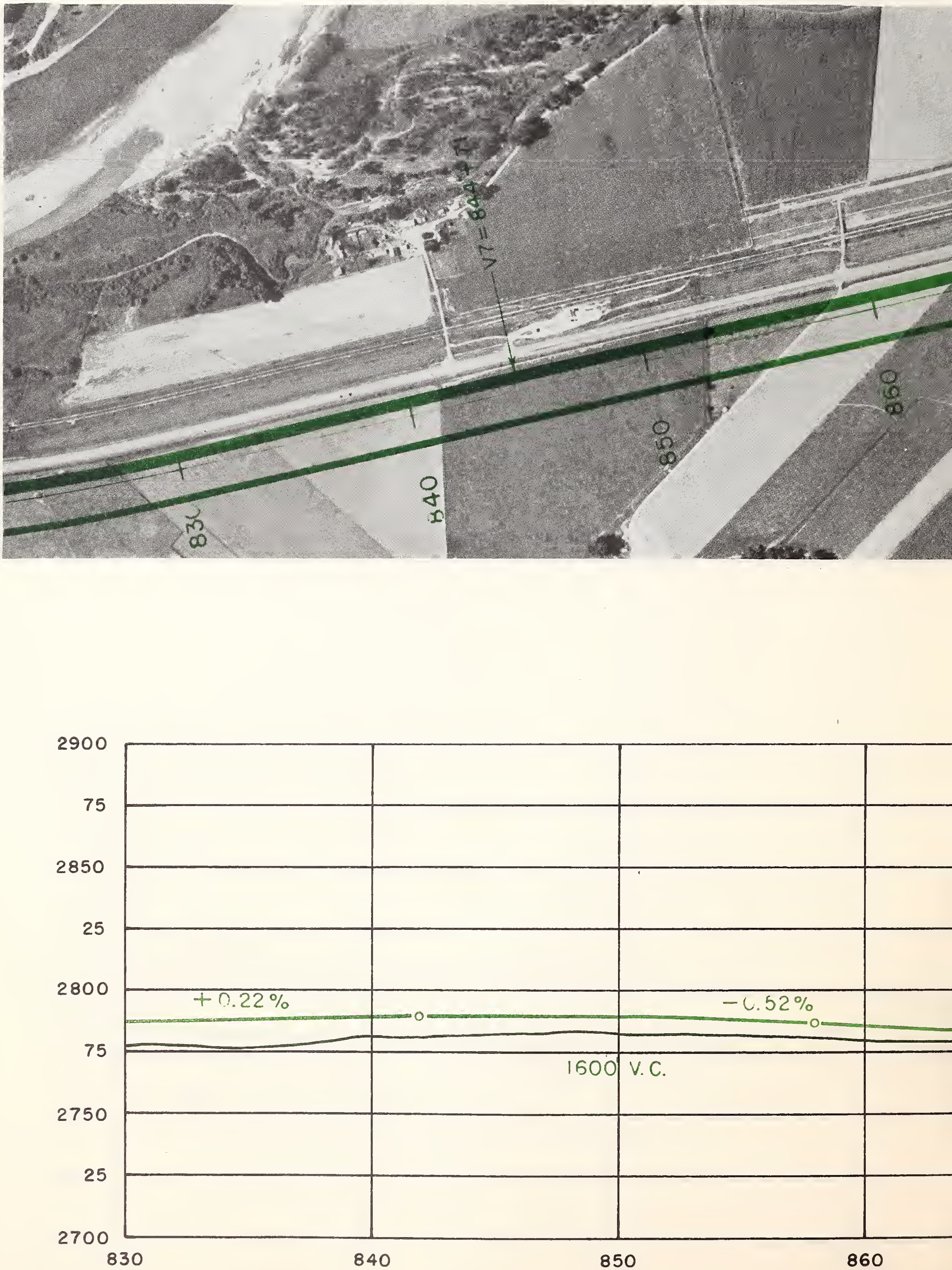
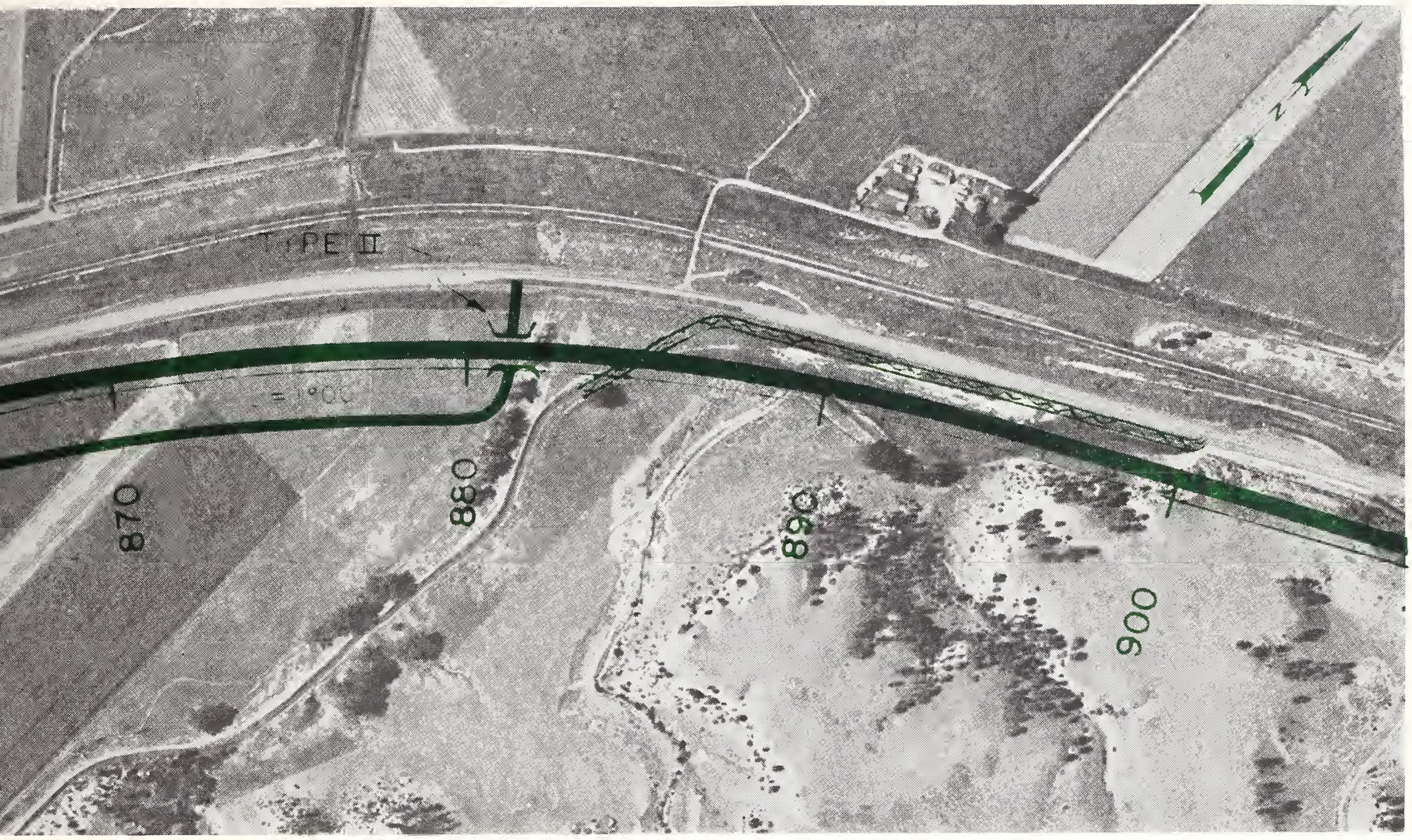

V6=804+66
D=1°00'
800
810
820
830
800' V.C.
+0.22%
72"
84"
2900
75
2850
25
2800
75
2750
25
2700
800
810
820
830

FIGURE 69



V7 = 844 + 71
830
840
850
860
2900
75
2850
25
2800
75
2750
25
2700
830
840
850
860
+ 0.22 %
− 0.52 %
1600 V.C.


TYPE II
= 1°00'
870
880
890
900
N

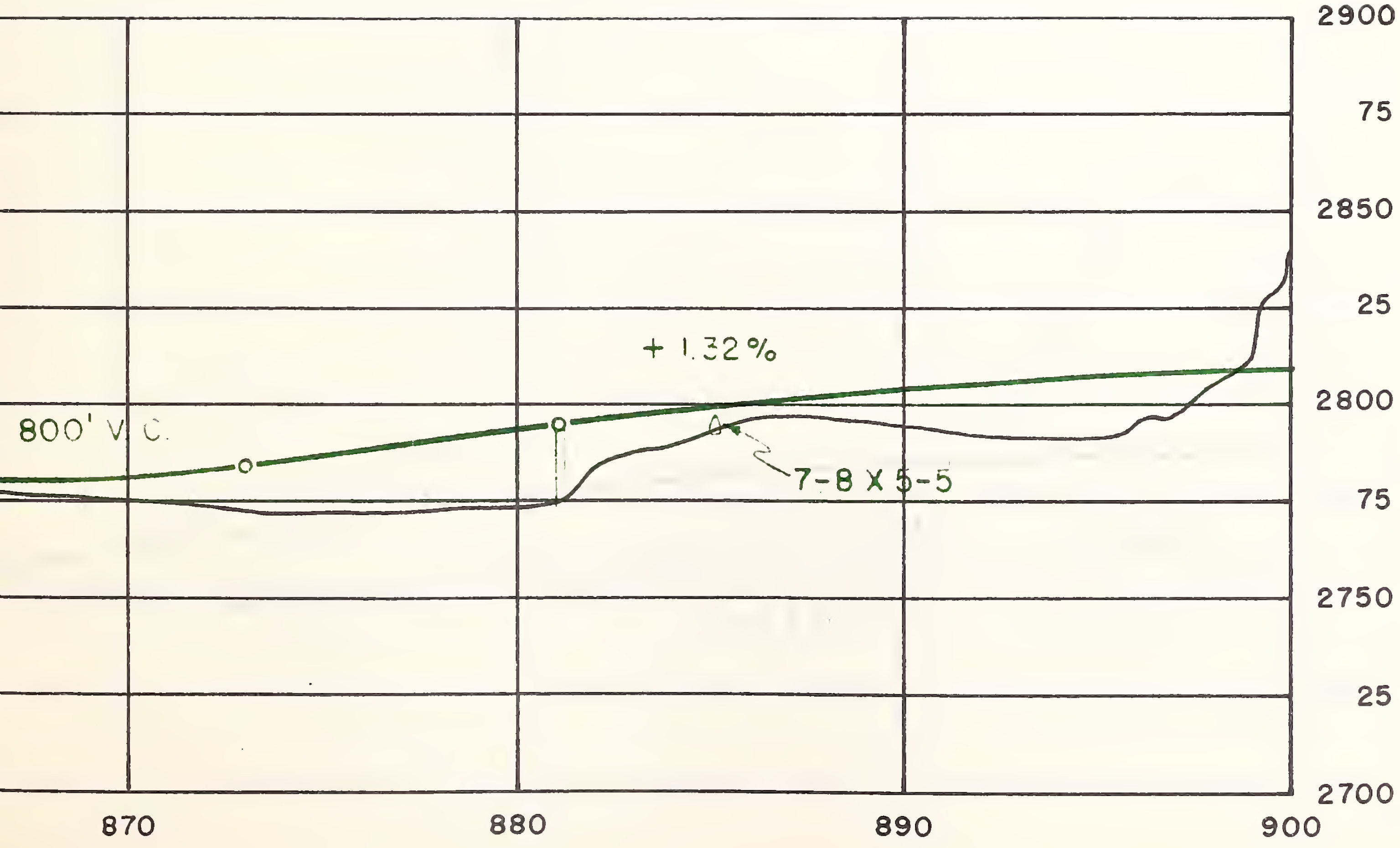
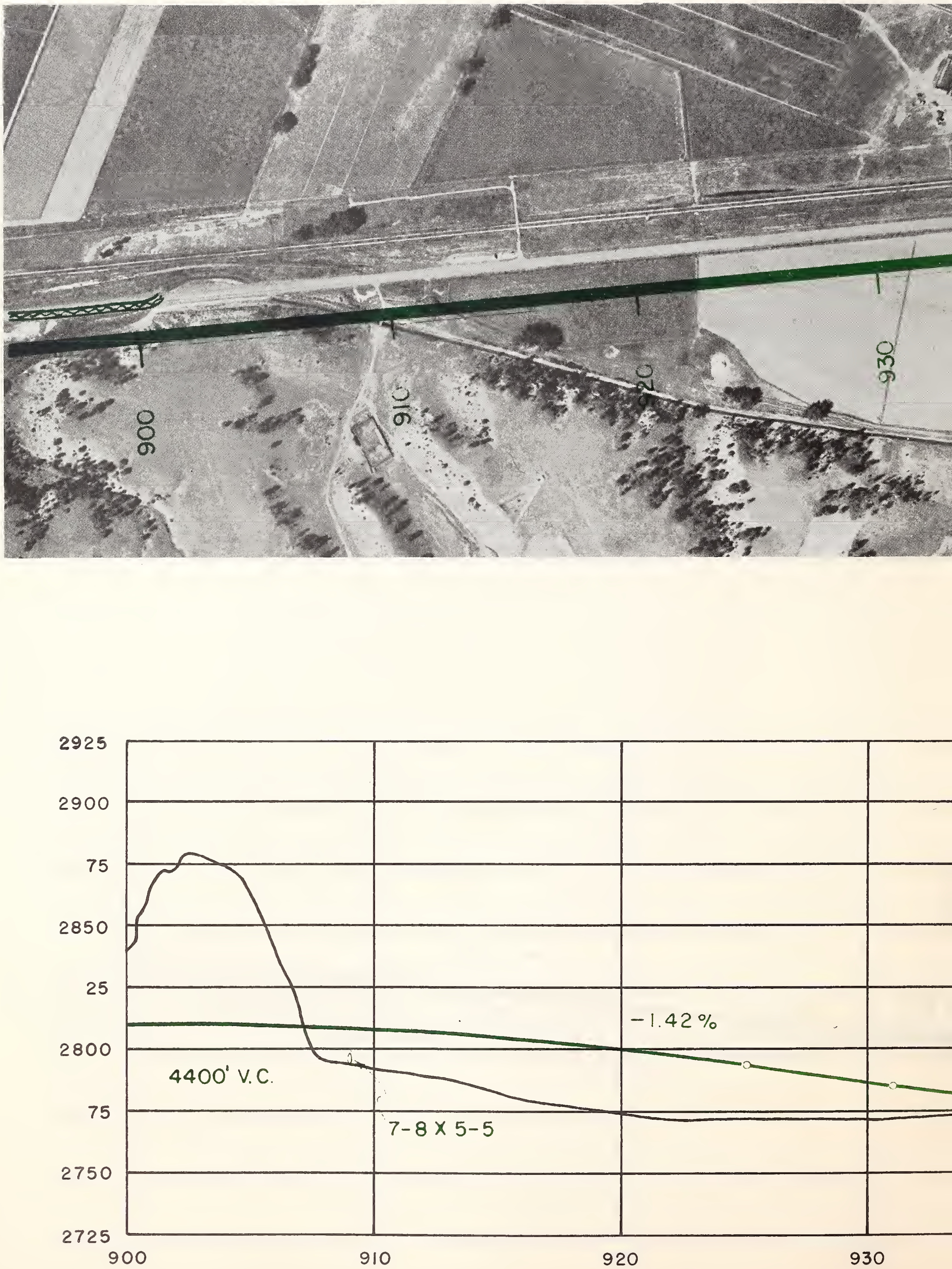

2900
75
2850
25
2800
75
2750
25
2700
+ 1.32 %
800' V. C.
7-8 X 5-5
870
880
890
900

FIGURE 71



900
910
920
930
2925
2900
75
2850
25
2800
75
2750
2725
-1.42 %
4400' V.C.
7-8 X 5-5
900
910
920
930

FIGURE 72

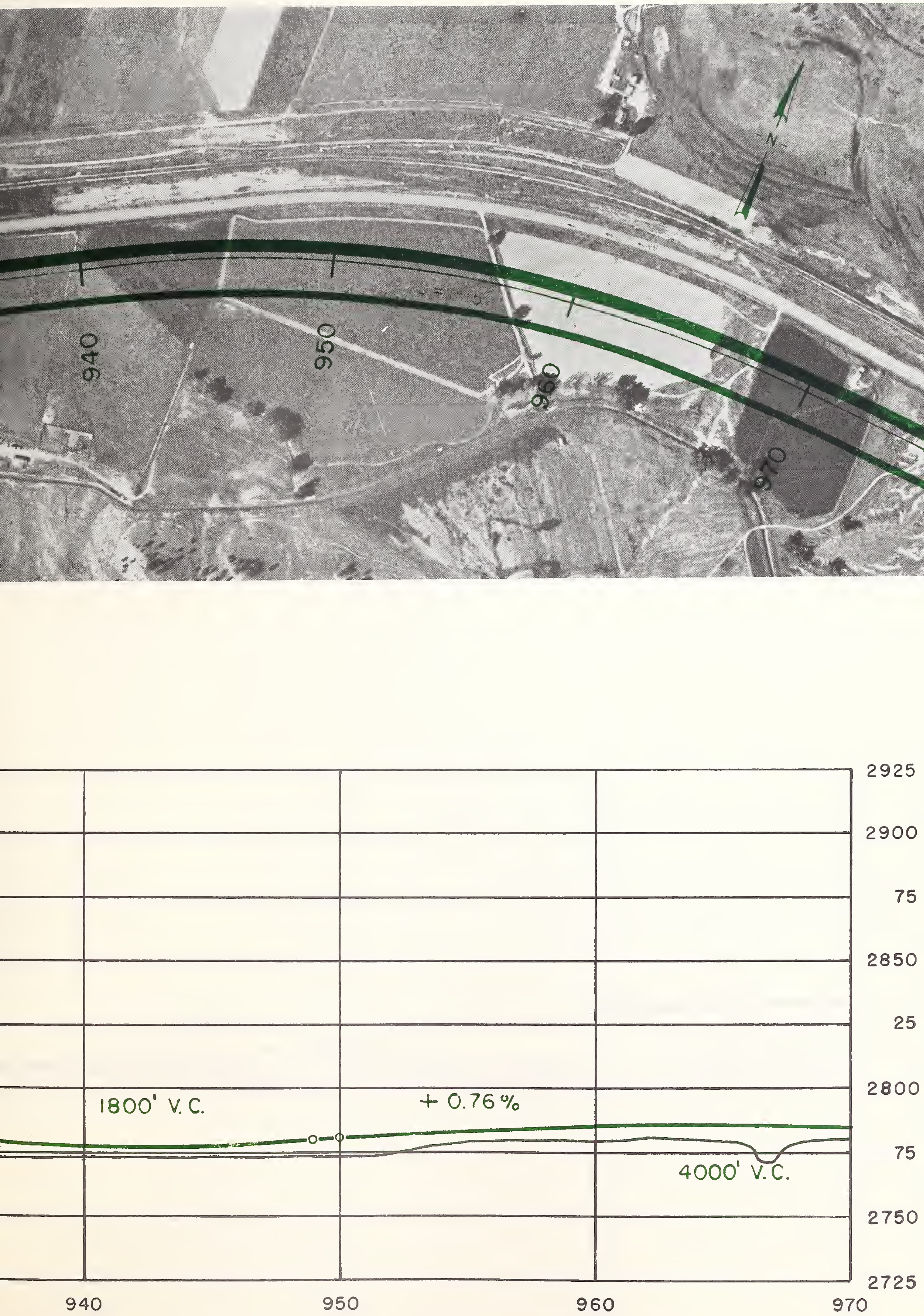
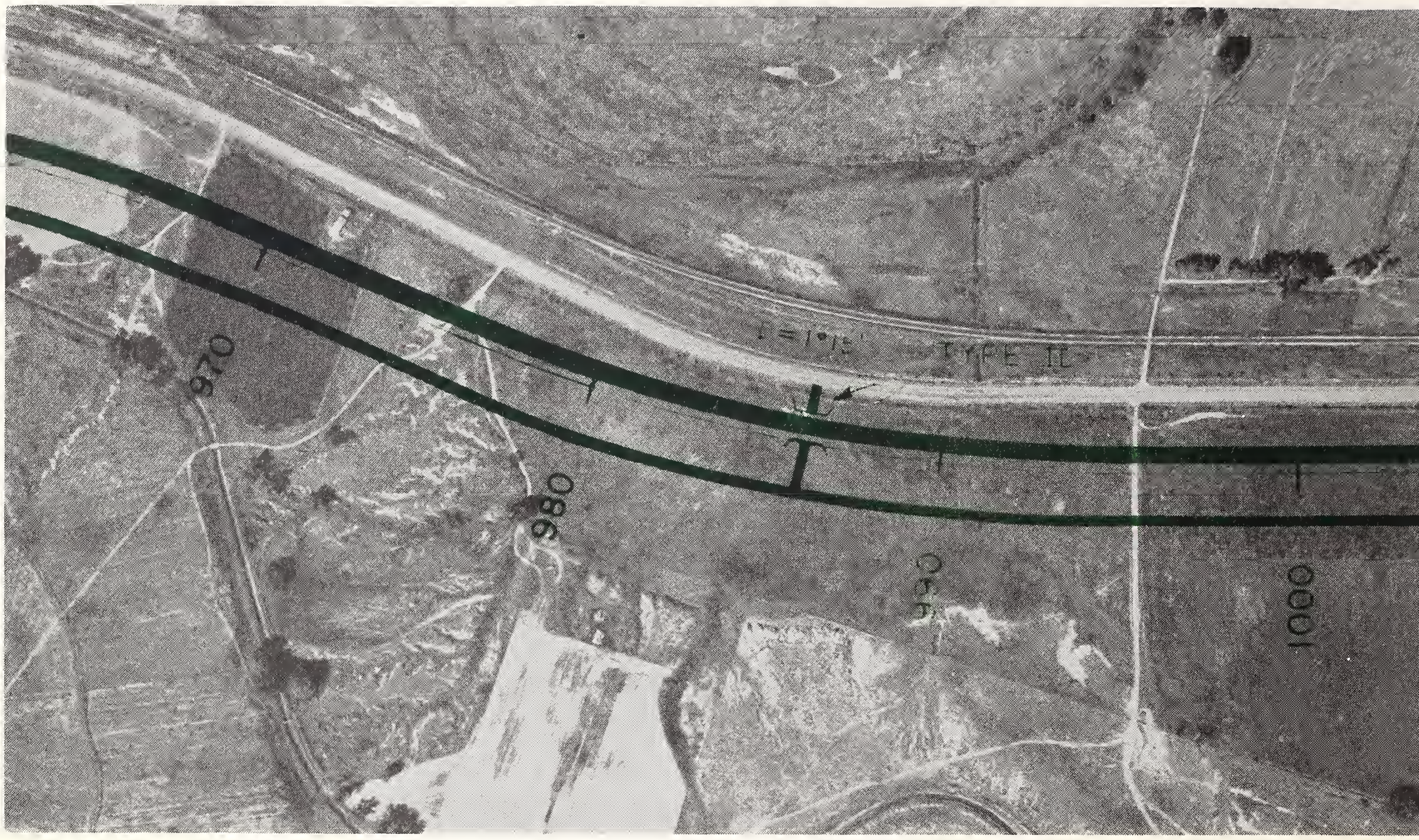
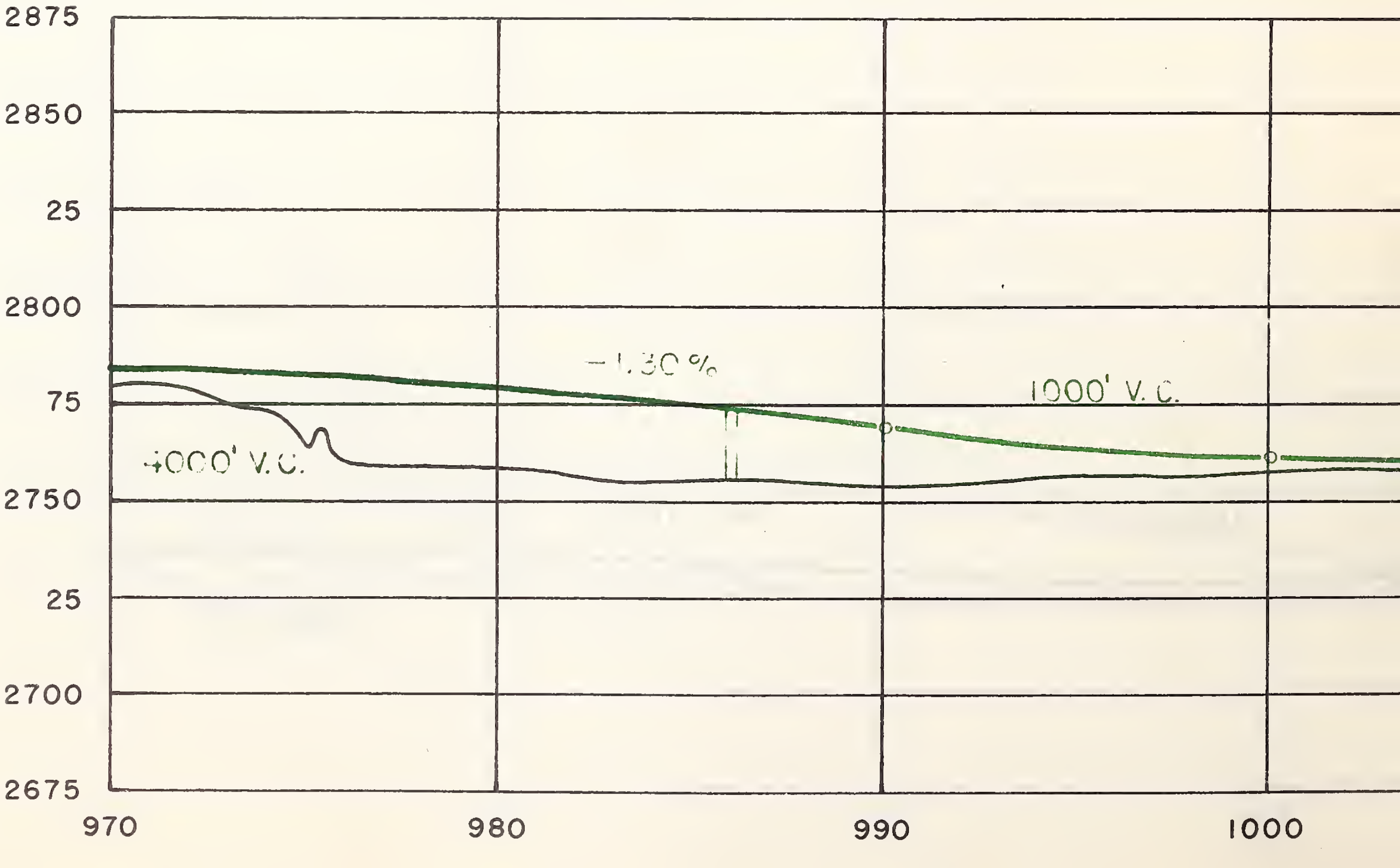

N
940
950
960
970
2925
2900
75
2850
25
2800
75
2750
2725
1800' V.C.
+ 0.76 %
4000' V.C.
940
950
960
970

FIGURE 73



I=1°15'
TYPE II
970
980
990
1000



2875
2850
25
2800
75
2750
25
2700
2675
-1.30 %
1000' V. C.
4000' V. C.
970
980
990
1000

FIGURE 74

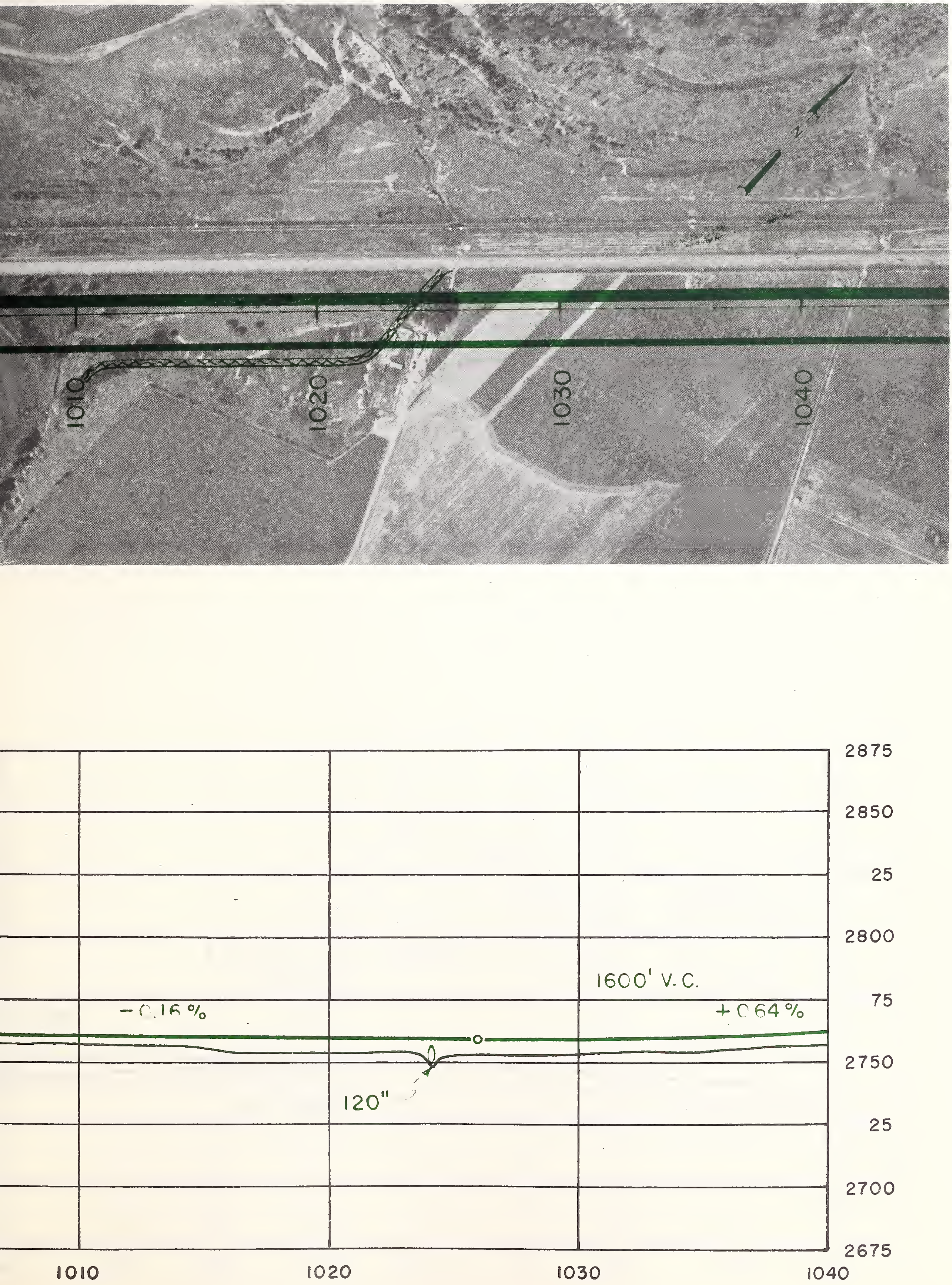

N
1600' V.C.
−0.16 %
+0.64 %
120"

FIGURE 75

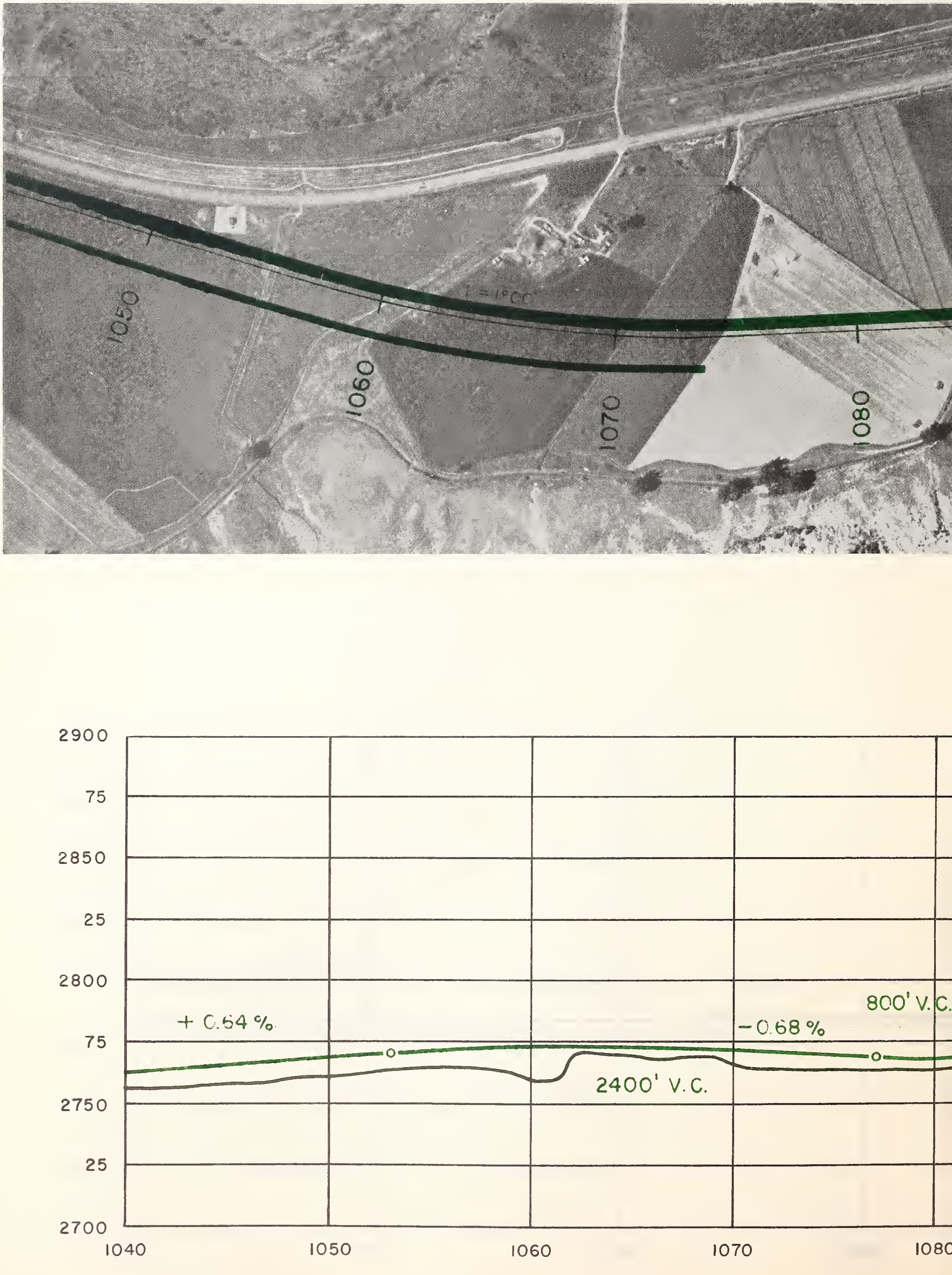

I = 1°00'
1050
1060
1070
1080
2900
75
2850
25
2800
75
2750
25
2700
1040
1050
1060
1070
1080
+ 0.64 %
- 0.68 %
800' V.C.
2400' V.C.

FIGURE 76

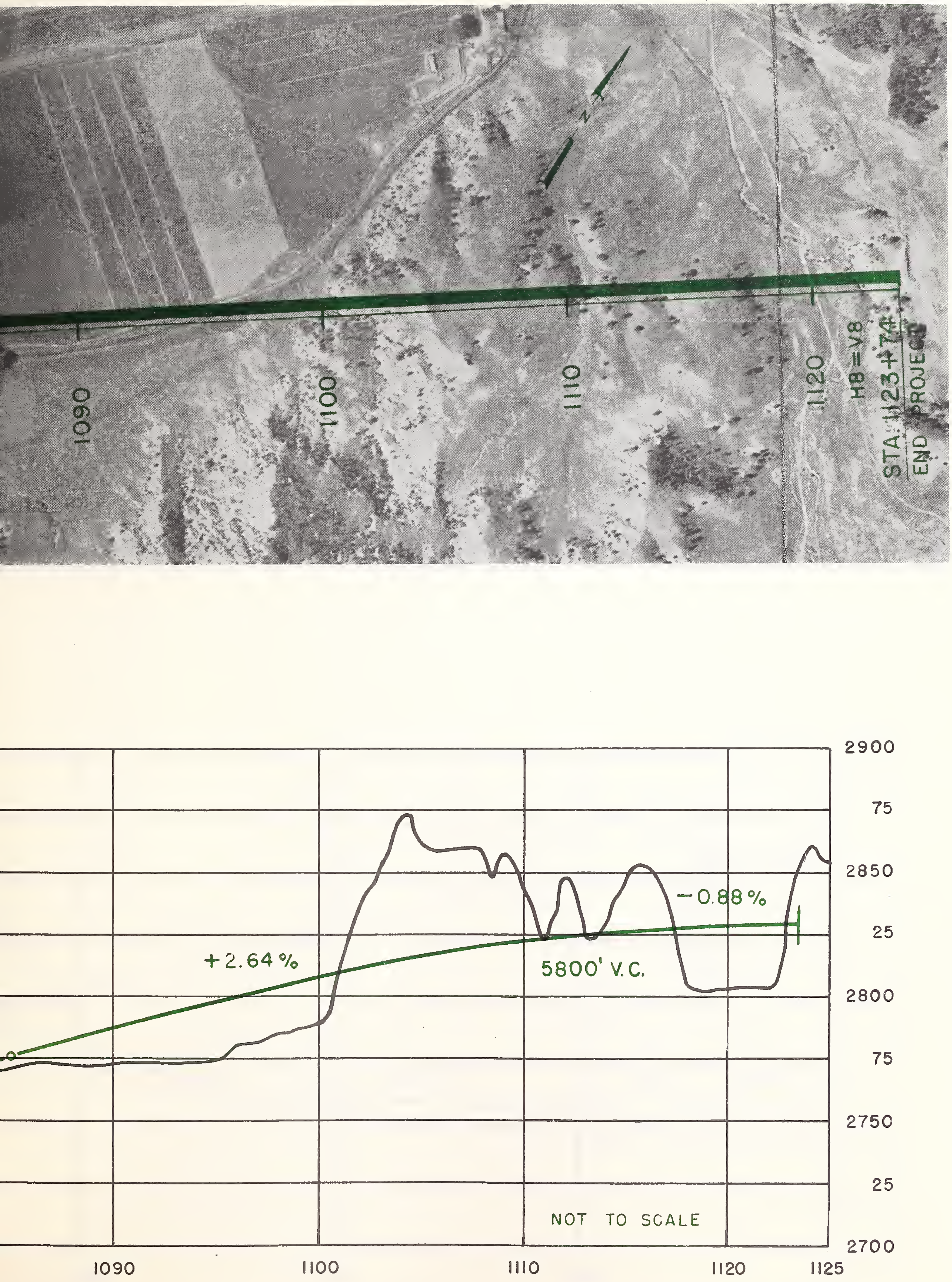
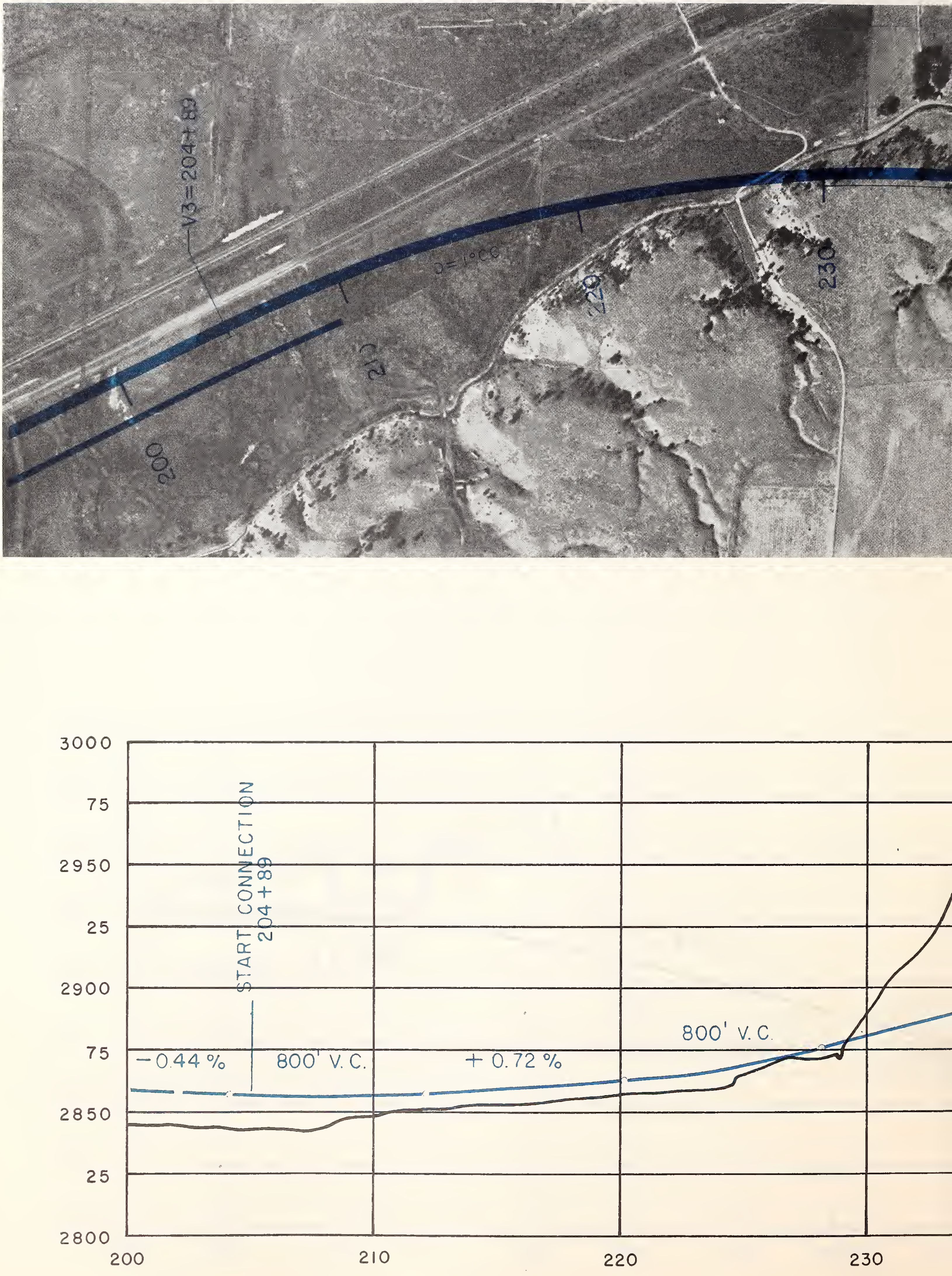
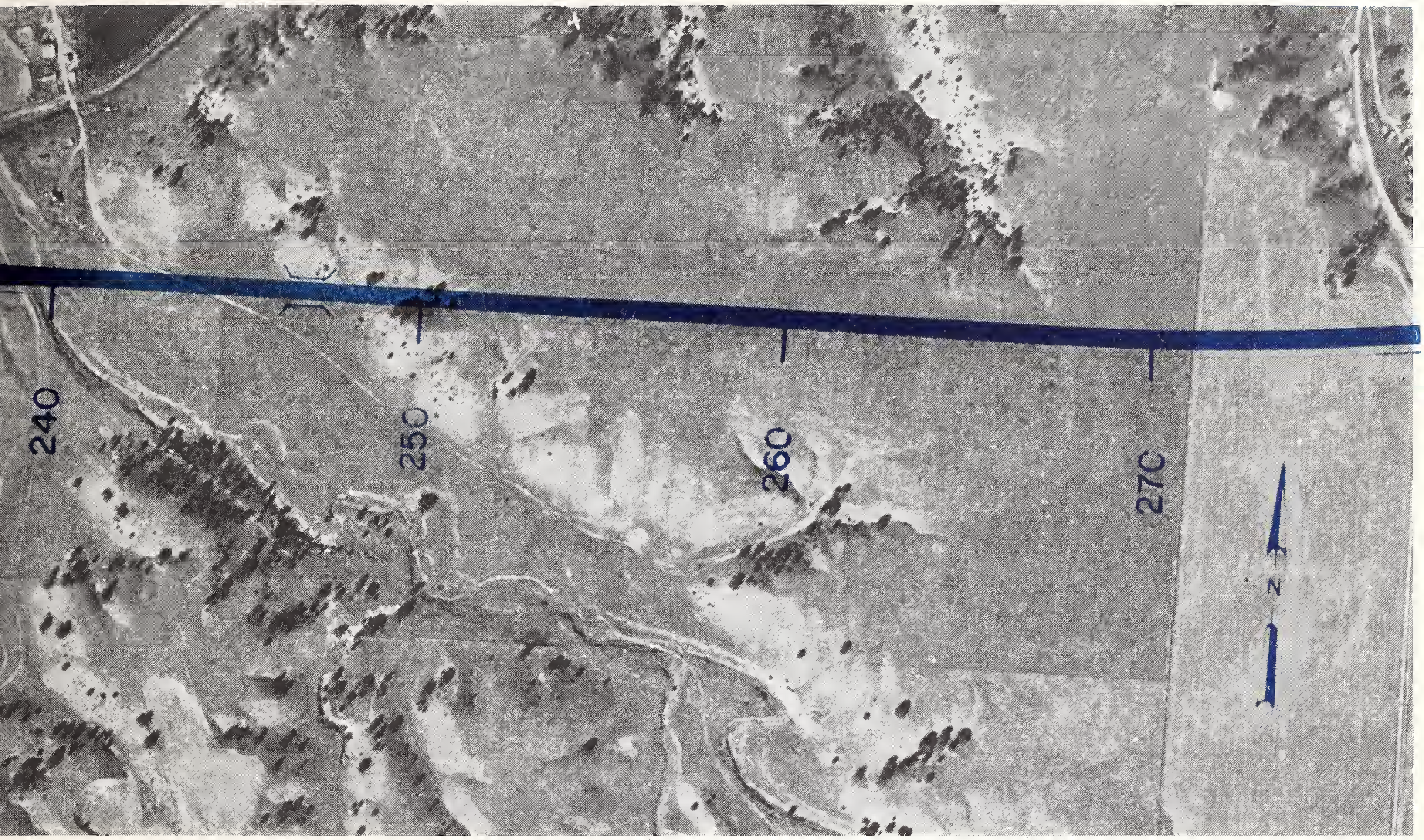
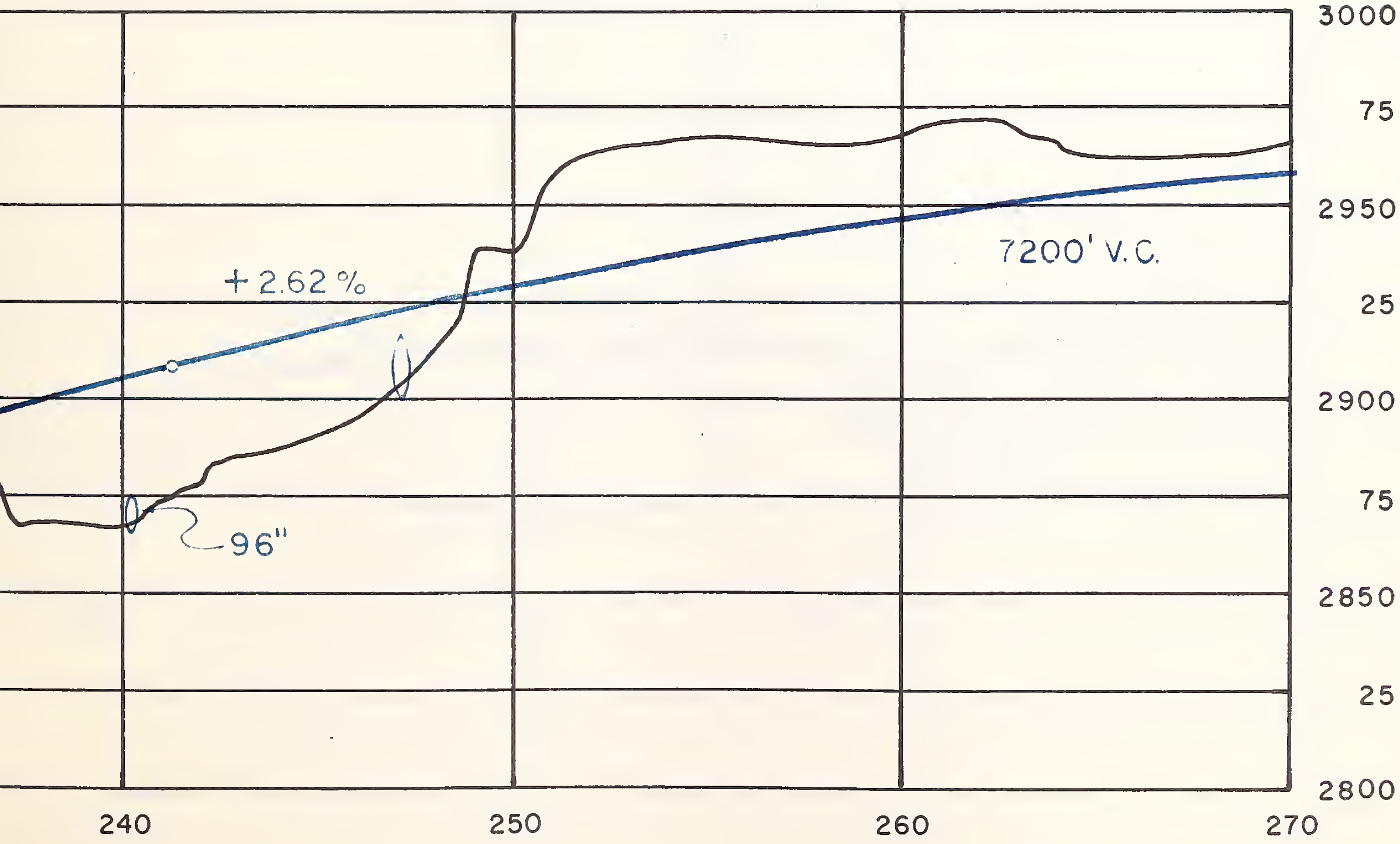

N
1090
1100
1110
1120
H8 = V8
STA. 1123+74
END PROJECT
2900
75
2850
25
2800
75
2750
25
2700
+2.64 %
5800' V.C.
−0.88 %
NOT TO SCALE
1090
1100
1110
1120
1125

FIGURE 77


V3=204+89
D=1°00'
200
210
220
230
3000
75
2950
25
2900
75
2850
25
2800
START CONNECTION
204+89
−0.44 %
800' V. C.
+ 0.72 %
800' V. C.
200
210
220
230



240
250
260
270
N



3000
75
2950
25
2900
75
2850
25
2800
+ 2.62 %
7200' V.C.
96"
240
250
260
270

FIGURE 79

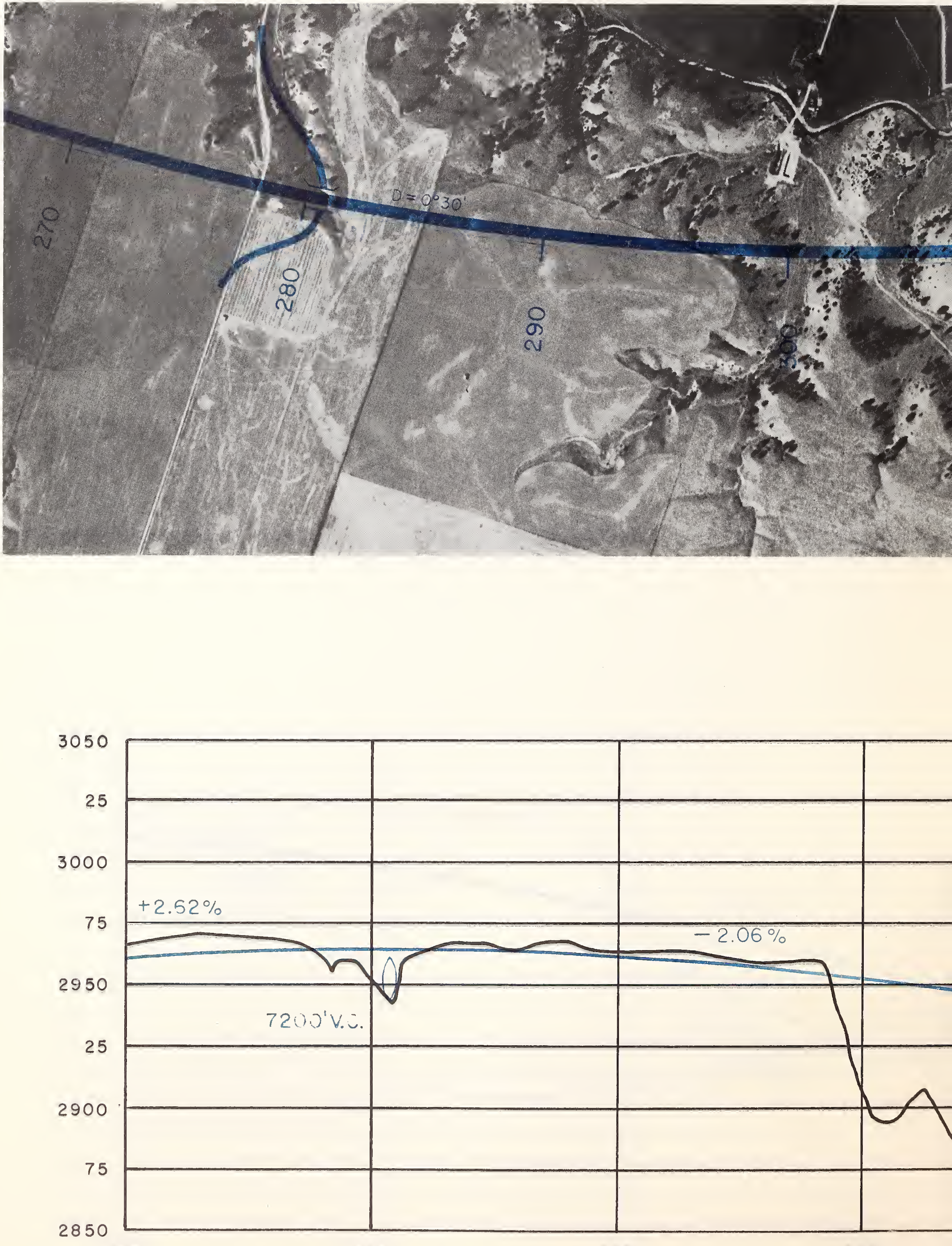

D = 0°30'
270
280
290
300
3050
25
3000
75
2950
25
2900
75
2850
+2.62%
− 2.06 %
7200'V.C.
270
280
290
300

FIGURE 80

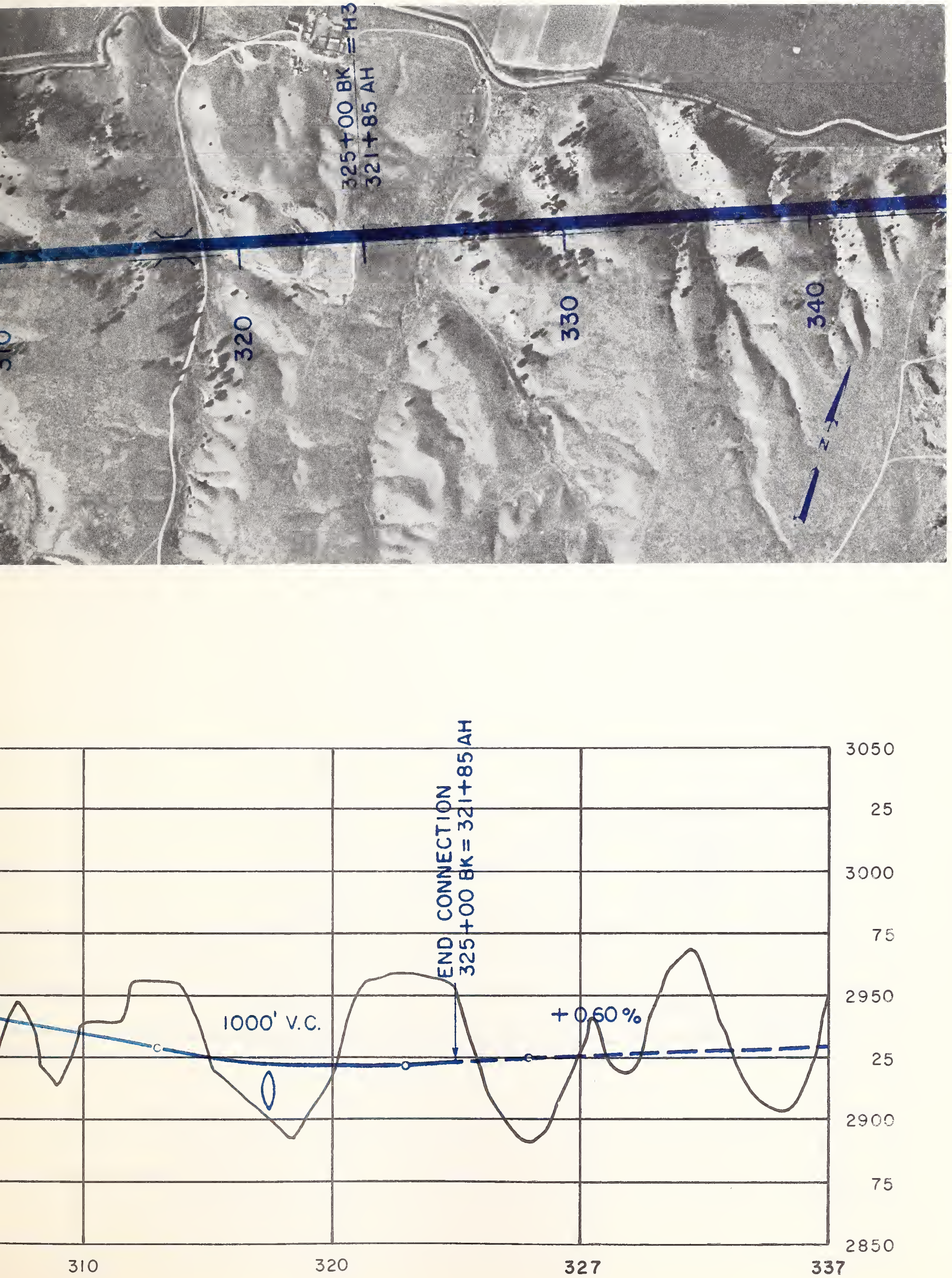
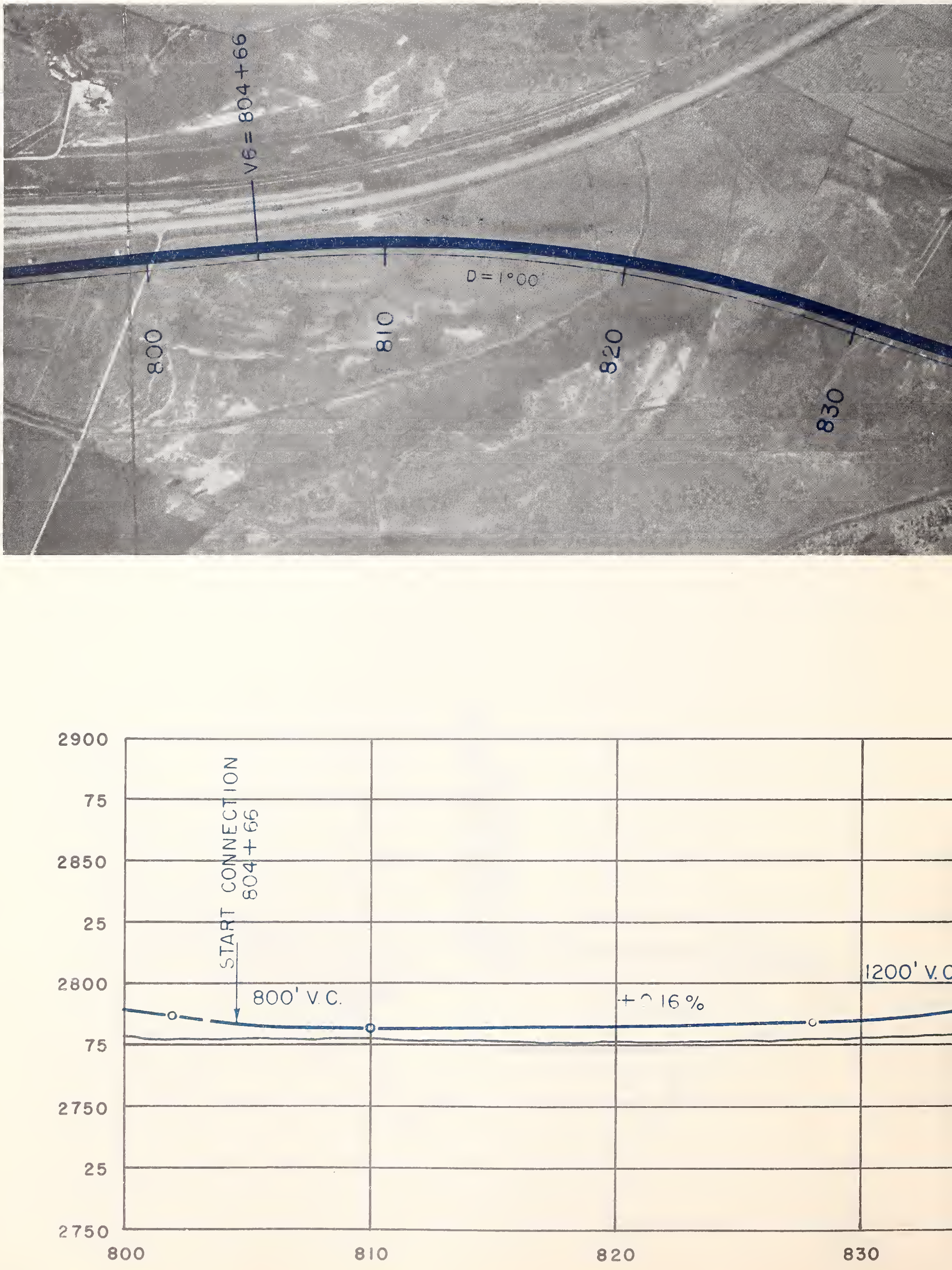

325+00 BK
321+85 AH
= H3
310
320
330
340
N
END CONNECTION
325+00 BK = 321+85 AH
1000' V.C.
+ 0.60 %
3050
25
3000
75
2950
25
2900
75
2850
310
320
327
337

FIGURE 81


V6 = 804+66
D = 1°00'
800
810
820
830
2900
75
2850
25
2800
75
2750
25
2750
START CONNECTION
804+66
800' V.C.
+0.16 %
1200' V.C
800
810
820
830

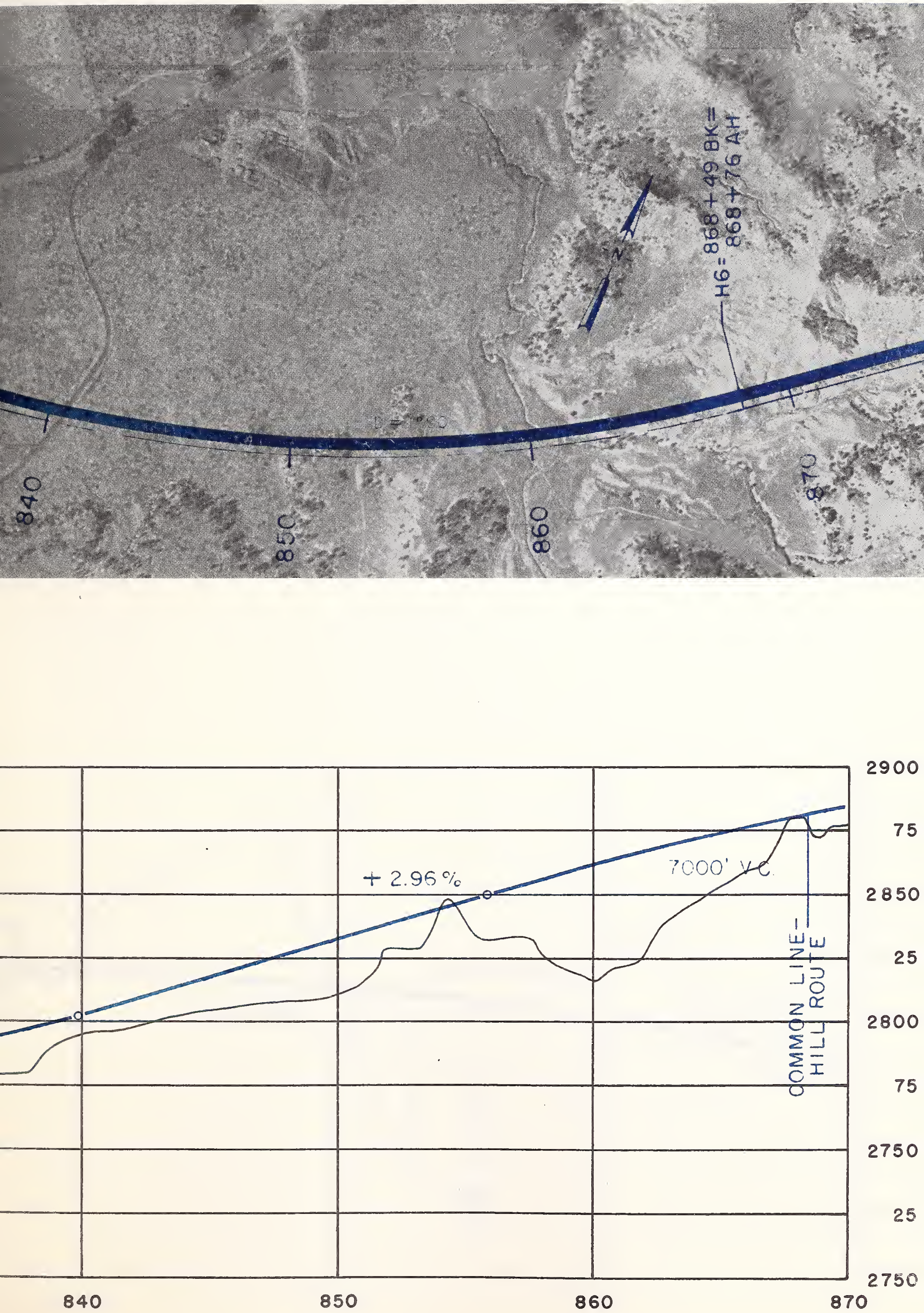


FIGURE 82

840
850
860
870
H6= 868+49 BK=
868+76 AH
N
+ 2.96 %
7000' V.C.
COMMON LINE–
HILL ROUTE
2900
75
2850
25
2800
75
2750
25
2750
840
850
860
870

FIGURE 83

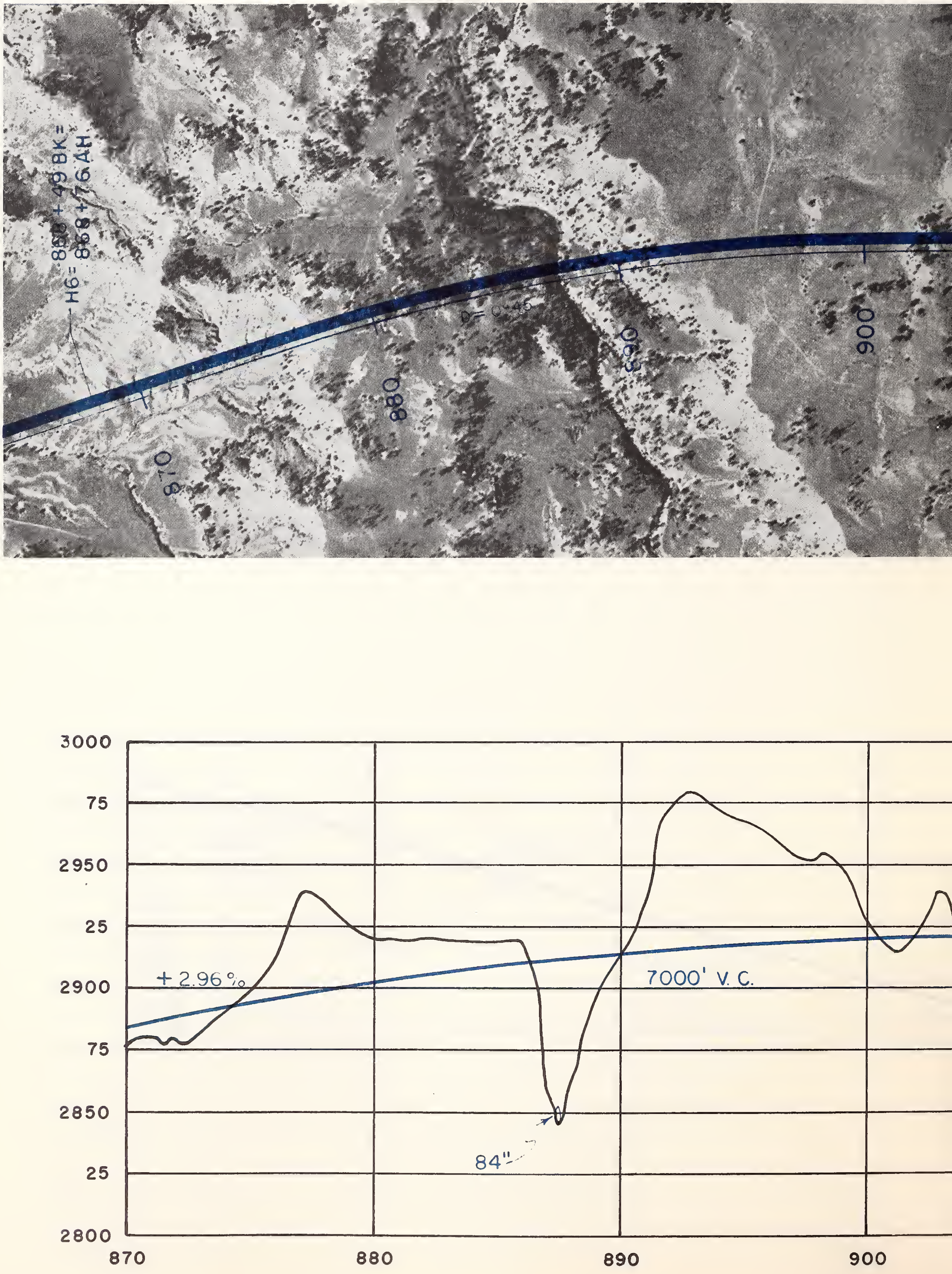
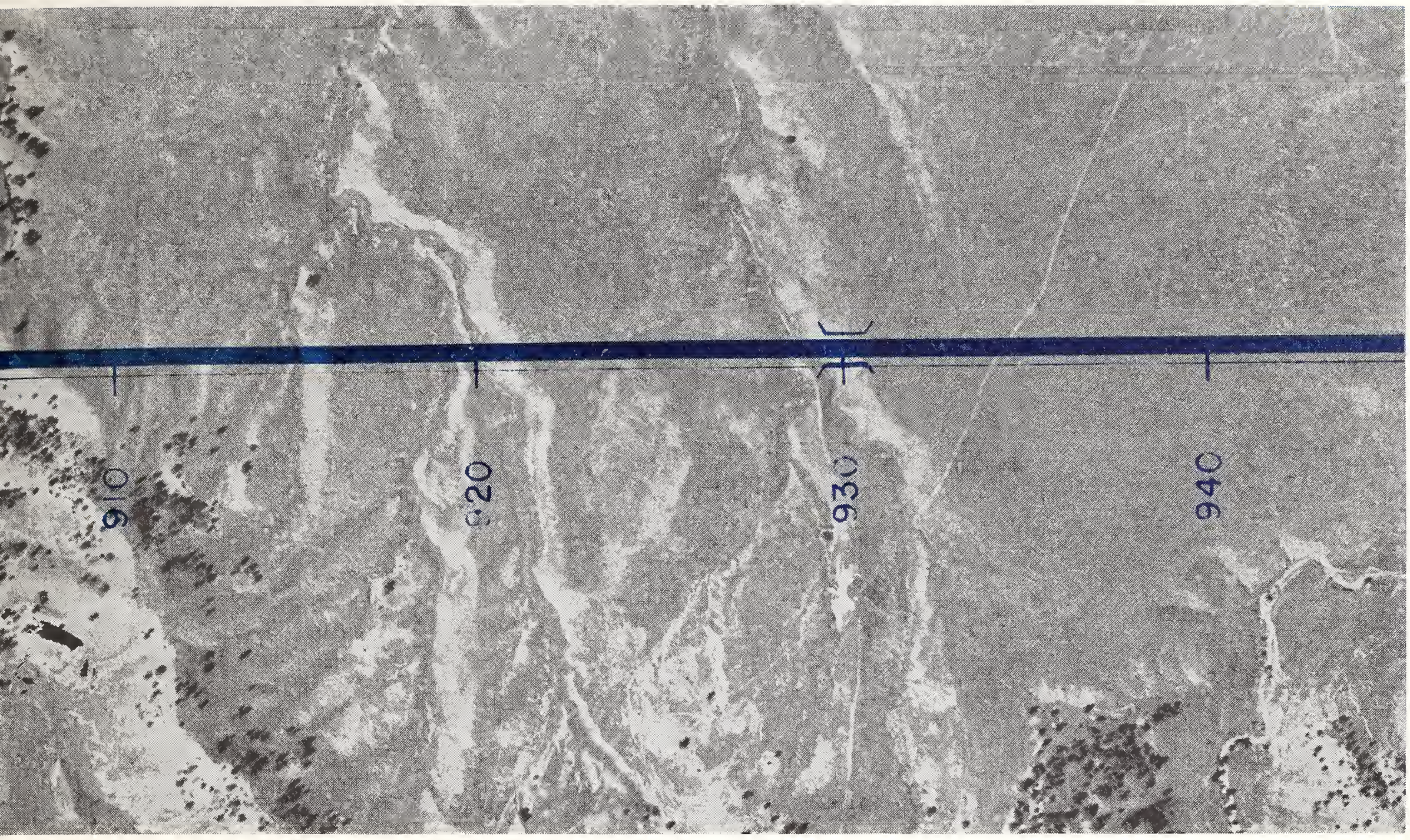

H6= 868 + 49 BK=
868+76 AH
D= 0°45'
870
880
890
900
3000
75
2950
25
2900
75
2850
25
2800
870
880
890
900
+ 2.96 %
7000' V. C.
84"

FIGURE 84


910
920
930
940

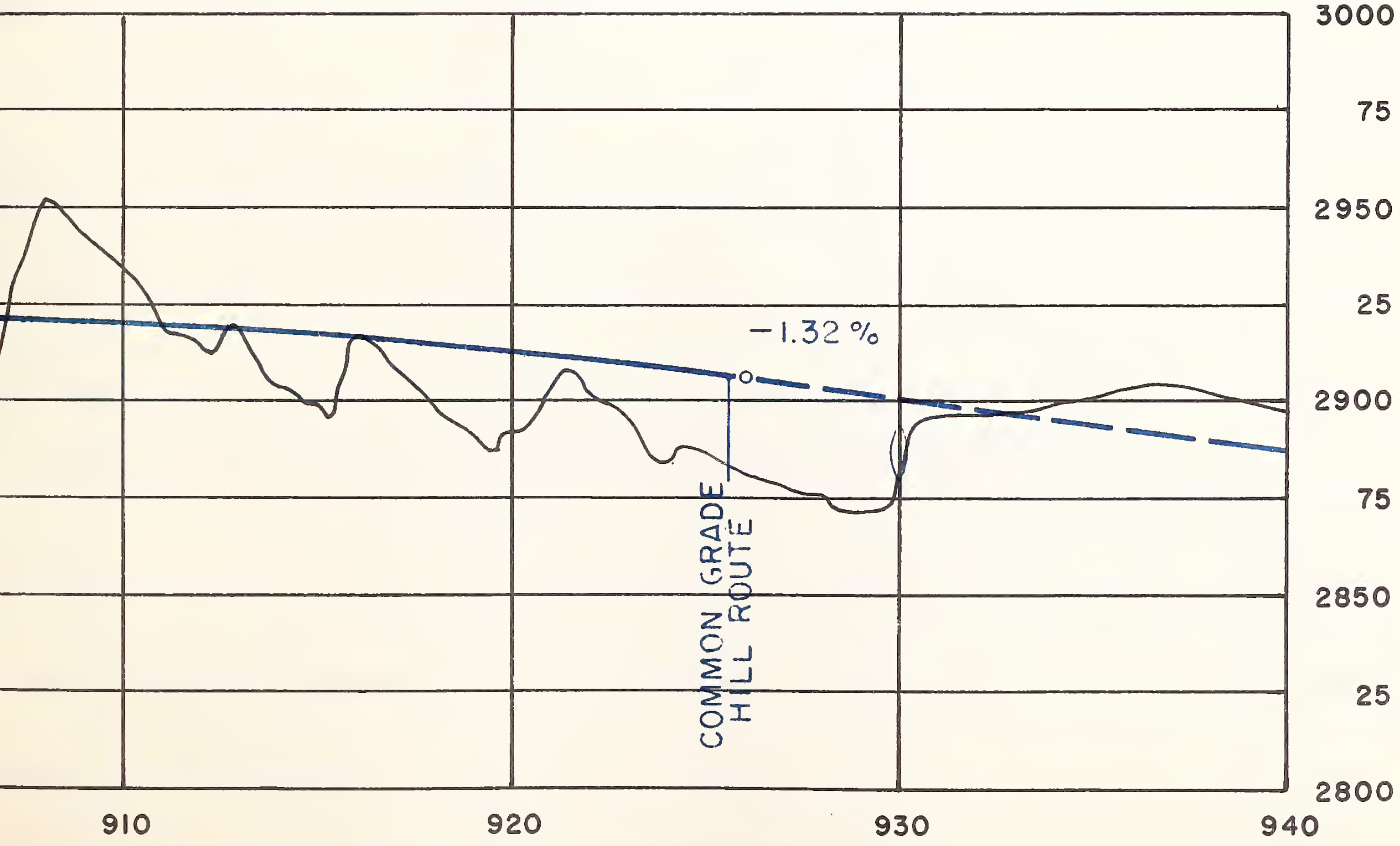

3000
75
2950
25
2900
75
2850
25
2800
-1.32 %
COMMON GRADE
HILL ROUTE
910
920
930
940

FIGURE 85

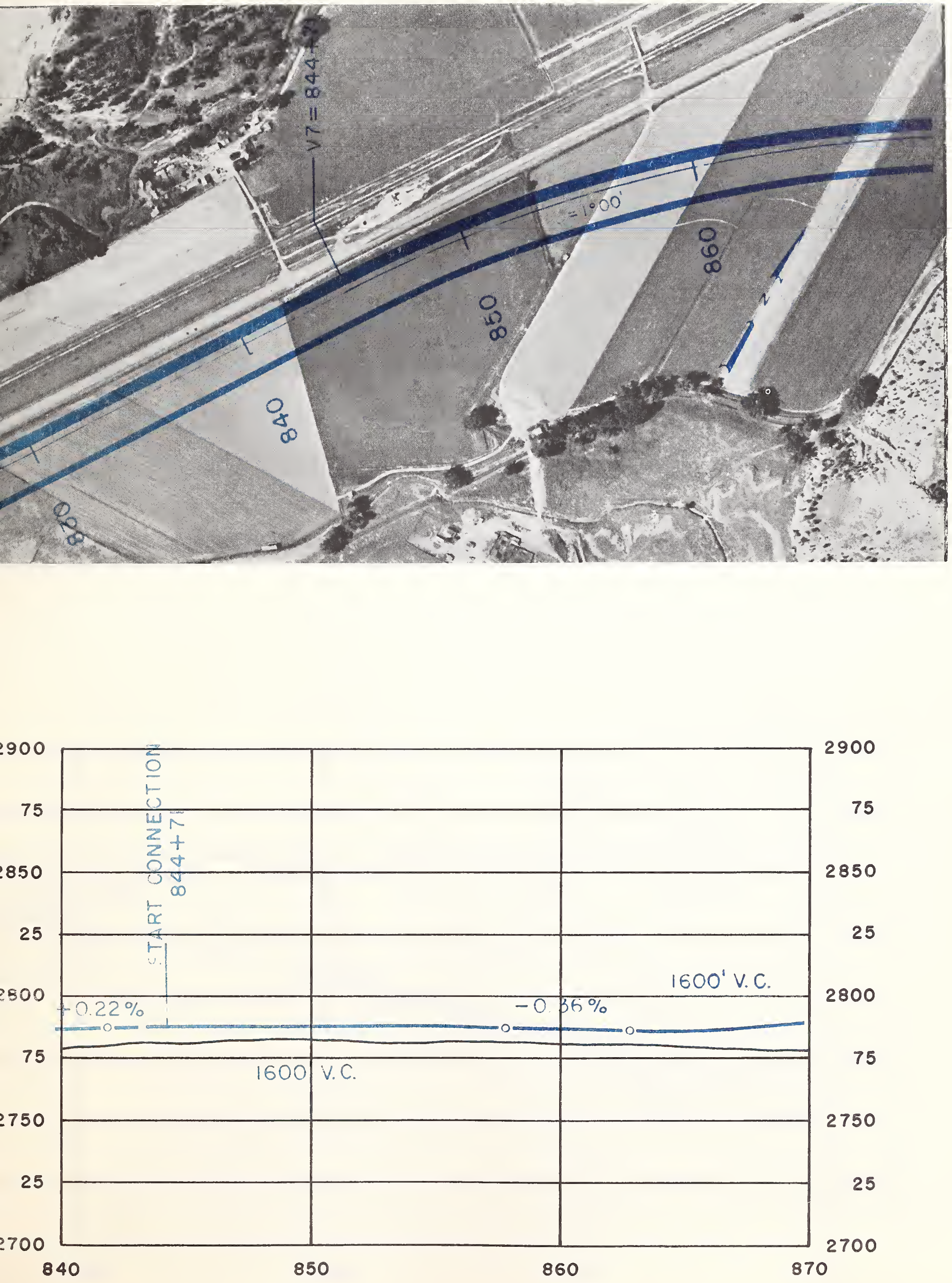
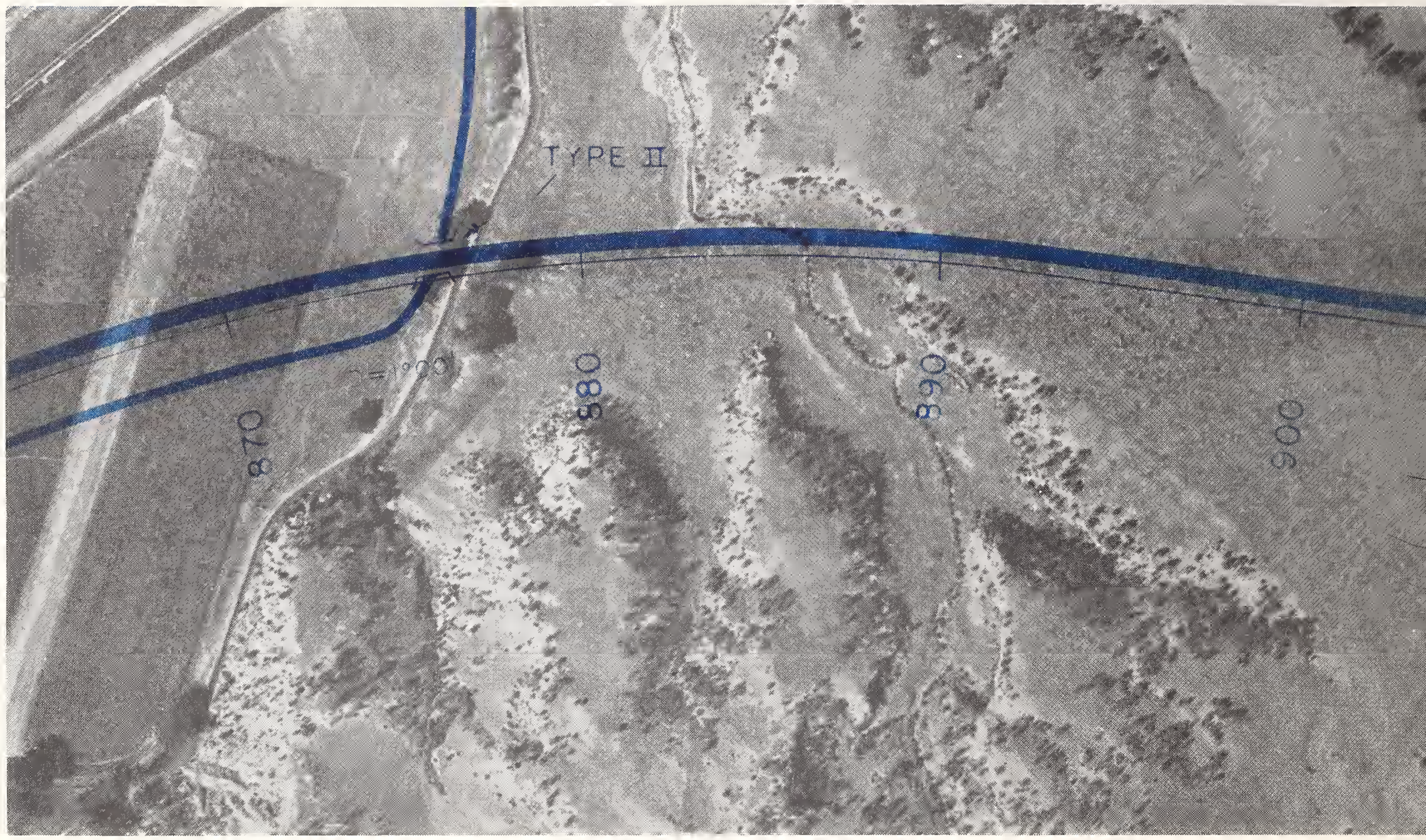

V7 = 844+7
=1°00'
830
840
850
860
N
START CONNECTION
844+7
+0.22%
−0.36%
1600' V.C.
1600' V.C.
2900
75
2850
25
2800
75
2750
25
2700
840
850
860
870

FIGURE 86


TYPE II
=1900
870
880
890
900

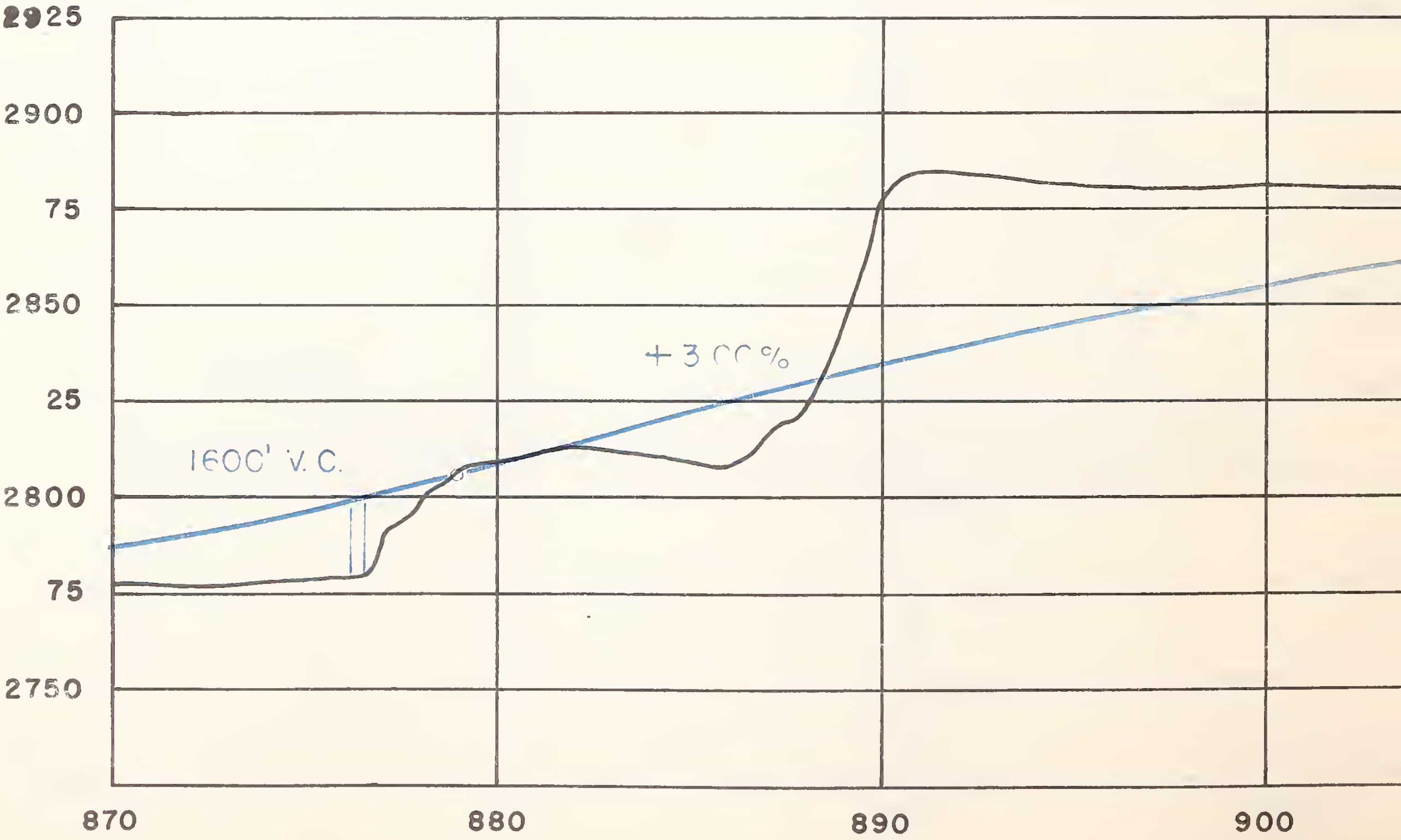
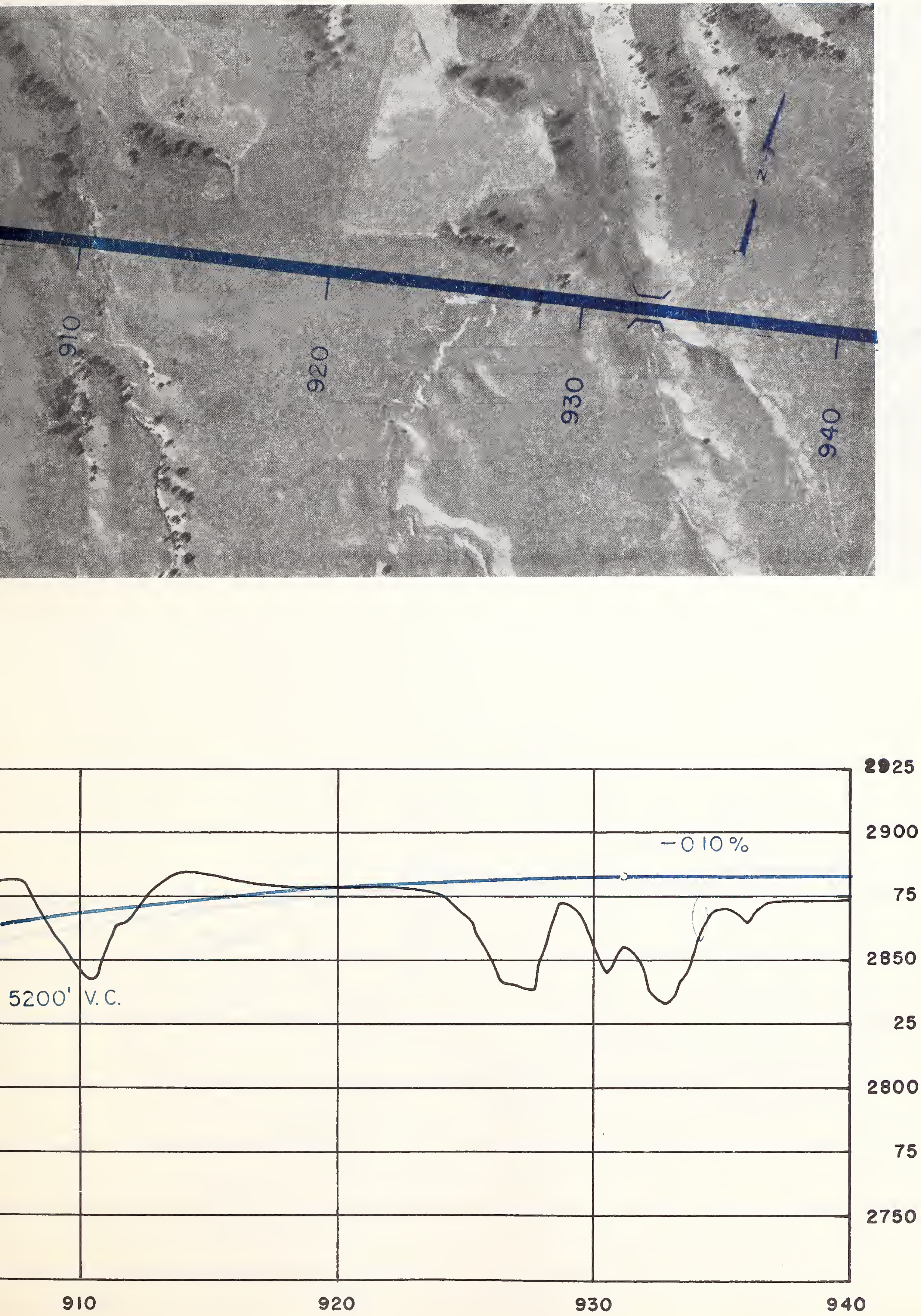

2925
2900
75
2850
25
2800
75
2750
1600' V.C.
+3.00%
870
880
890
900

FIGURE 87



N
910
920
930
940
−0.10 %
5200' V.C.
2925
2900
75
2850
25
2800
75
2750
910
920
930
940

FIGURE 88

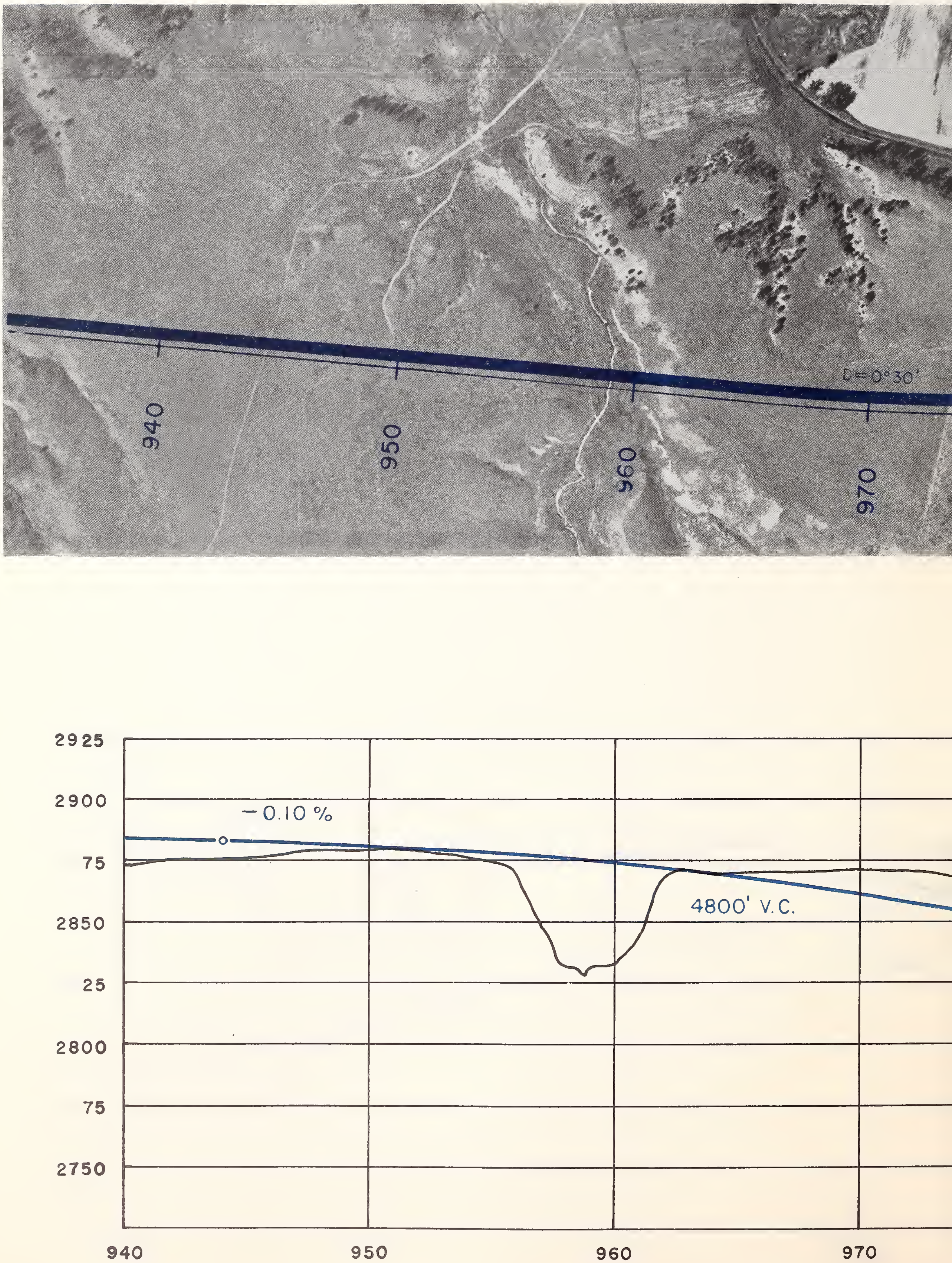
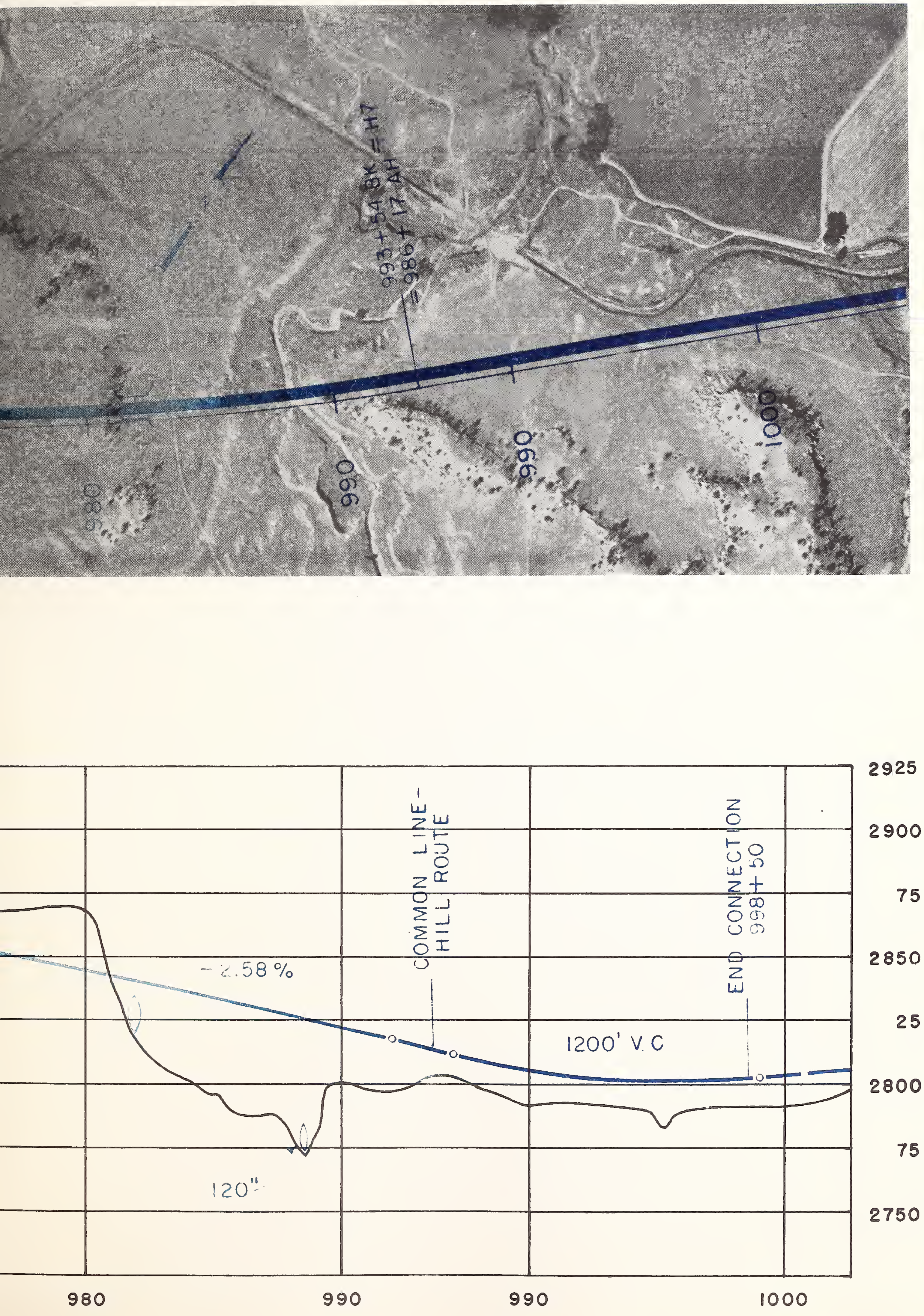

940
950
960
970
D=0°30'
2925
2900
75
2850
25
2800
75
2750
−0.10 %
4800' V.C.
940
950
960
970

FIGURE 89


993+54 BK = H7
= 986+17 AH
980
990
990
1000
COMMON LINE-
HILL ROUTE
END CONNECTION
998+50
−2.58 %
1200' V.C
120"
2925
2900
75
2850
25
2800
75
2750
980
990
990
1000